EDUCATOR

SELF-EDUCATOR

MARINE AND STATIONARY ENGINEERS CATECHISM

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SELF-EDUCATOR.

Rules to Find the Diameter, Circumference and the Area of a Circle

Q. Multiply the square of the diameter by the decimal .7854 will give the area.

Q. How do you square the diameter?

A. Any diameter multiplied by itself equals the diameter squared. For instance, 10 squared equals 100.

Q. Why do you multiply by .7854?

A. Square the diameter and we get the square inches in the square; if we multiply by .7854 we get the square inches in the circle, the circle being that fraction of the square.

Q. What do you mean by the word area?

A. By the area we mean the amount of surface exposed to the action of the steam.

Diameter × by 3.1416 is the circumference of a circle.

Diameter × by .8862 is the side of an equal square.

Diameter × by .7071 is the side of an inscribed square.

Diameter × by .7854 is the area of a circle.

Radius × by 6.28318 is the circumference.

Circumference ÷ 3.1416 is the diameter.

The area of a circle ÷ by .7854 and extract the square root will give the diameter of a circle.

Miscellaneous

A United States gallon contains 231 cubic inches.

A United States standard gallon weighs nearly 8.355 lbs.

A cubic foot of fresh water weighs 62.5 pounds.

A cubic foot of sea water weighs 64 pounds.

35 cubic feet of sea water weigh one ton.

32 cubic feet of fresh water weigh one ton, and weigh 62.5 pounds to a cubic foot.

2240 pounds weigh one ton.

A cubic foot of coal weighs 56 pounds.

5280 feet make one land mile.

6080 feet make one nautical mile.

1728 cubic inches make one cubic foot.

27 cubic feet is one cubic yard.

144 square inches in one square foot.

6 feet is one fathom.

360 degrees is the circumference of a circle.

7.48 gallons are in a cubic foot.

To get the circumference use 3.1416.

1760 yards is one mile.

To Reduce a Vulgar Fraction to a Decimal Fraction

Divide the numerator of the fraction by the denominator, adding ciphers to the numerator until it works out in four figures.

Example: Reduce $\frac{7}{8}$ to a decimal.

```
8)7.0000(.8750 decimal 7/8
  64
  --
   60
   56
   --
    40
    40
    --
```

Again: Reduce $\frac{3}{8}$ to a decimal.

```
8)3.0000(.3750 decimal of 3/8
  24
  --
   60
   56
   --
    40
    40
    --
```

Again: Reduce $\frac{5}{8}$ to a decimal.

8)5.0000(.6250 decimal of $\frac{5}{8}$

Again: Reduce $\frac{5}{16}$ to a decimal.

```
16)5.0000(.3125 decimal of 5/16
    48
    --
     20
     16
     --
      40
      32
      --
       80
       80
       --
```

Cube Root

When a number is multiplied by itself twice it is called the cube of the number, as the cube of 4 is 64, because $4 \times 4 = 16$ and $16 \times 4 = 64$, or $4 \times 4 \times 4 = 64$. The cube root of a number is the number the cube of which equals the number. The sign over a number expresses the cube of the number. Thus 5^3 denotes the cube of 5, $= 5 \times 5 = 25 \times 5 = 125$ or $5 \times 5 \times 5 = 125$ thus $\sqrt[3]{125} = 5$.

Proportions

Engineers should be thorough masters of the principles of proportion, as nearly all questions of consumption and speed can be solved by it quicker than by any other rules. In proportions, if the answer is to be greater, make the second term the greater. As you will notice in the following example, the answer was greater because 12 men could earn more than 5 men, and if it is to be smaller or less, make it the second term. Always let this be your guide, for if the answer is to be smaller, make the second term the smaller, and if it is to be larger, make the second term the larger.

Example

```
men
5:12::30        12
                 30
                ---
              5)360(72 answer
                35
                ---
                 10
                 10
                 --
```

If it takes 8 hours to walk 25 miles, how long will it take to walk 60 miles at the same gait. The answer in this problem is to be greater, so 60 miles will be the second term.

```
25:60::8 hours     60 miles
                    8
                  -----
               25)480.0(19.2
                  25
                  ---
                  230
                  225
                  ----
                    50
                    50
                    --
```

If the repairs to an engine take 9 men 18 days to do a job, how long will 16 men take to do it. The answer is to be smaller, as 16 men will do the work in less time, so we make 9 men the second term: 16:9::18 = 10 days.

```
          18
           9
          ---
      16)162(10 days
          16
          ---
            2
```

Square Root

When a number is multiplied by itself it is said to be squared, and is called the square of the number. As $8 \times 8 = 64$ is the square of 8, the square root of any number is the number whose square is equal to the number given. The square root of any number up to one hundred may easily be found without working out, as the square root of 36 is 6 because $6 \times 6 = 36$ again $\sqrt{81} = 9$; $\sqrt{100} = 10$. To get the square root of a large number, proceed as follows: write down the number that the square root has to be extracted from. Mark two figures, counting from the right to the left in whole numbers, and from the decimal point to the right point off every two figures to the left. To get the square root of 622521:

```
      62|25|21(789 answer
      49
      ----
 148) 1325
      1184
      -----
1569) 14121
      14121
      -----
```

Get the square root of

```
      31|83|00(5.64 answer
      25
      ---
 106) 683
      636
      ----
1124) 4700
      4496
      ----
```

Get the square root 1|44(12 *answer*

```
     1|44(12 answer
     1
     ---
 22) 044
      44
     ---
```

Practical Questions

Q. What type of boilers are mostly used for marine work?

A. The Scotch boiler on land vessels and tugs.

Q. What boilers are mostly used on land?

A. The return tubular boiler set in brickwork.

Q. Name the important parts to be looked after on a boiler. Leaving out for the present the question of whether the boiler was properly designed originally.

A. The exterior of the boiler should be examined for corrosion, expecially at the fire line and around the ash pits if it is surrounded by water space. The surface exposed to the fire should be examined for blisters, and if any appear they should be cut with a chisel so that their depth and extent should be known.

Q. Have you noticed any scale on flues or crown sheets? If you did how would you remove it?

A. By using compound.

Q. How is the pitch or the distance found between the rivet holes in a boiler plate?

A. Divide the area of the hole by the thickness of the plate and add the diameter of one hole.

Q. What is the effect of using steam expansively?

A. Its effect is in the economy due to the use of the expanding of steam below the boiler pressure.

Q. What is meant by sensible heat and latent heat?

A. Sensible heat is that required to raise the temperature of water from freezing point to the temperature of steam. Latent heat is that required to evaporate the water at the given temperature or the heat which disappears in effecting the converting of water into vapor.

Q. Have you noticed any bulging in the fire-box plates? If you found a thin place in your boiler what would you do?

A. Put a patch on it.

Q. Would you put a patch on the outside?

A. No; put it on the inside.

Q. Why so?

A. Because the action that has weakened the plate will then act on the patch, and when this is worn it can be replaced; but the plate remains as we found it if the patch were put on the outside. The action would still be on the patch, which would in time be worn through, then the pressure of steam would force the water between the plate and the patch, and so corrode it, and during an extra pressure the patch might blow off.

Q. If you found several thin plates what would you do?

A. Patch each one and reduce the steam pressure.

Q. If you found a blistered plate what would you do?

A. Put a patch on the fire side of the boiler.

Q. If you found a plate at the bottom buckled?

A. Put a stay through the centre of the buckle.

Q. If you found several buckles?

A. Stay each one and reduce the steam pressure.

Q. If the crown of a furnace were down, what then?

A. Jack it up or put a bolt through the middle and a dog across the top if the furnace were down. Lengthwise, put a series of bolts and dogs.

Q. If you had a crack, what would you do?

A. Drill a hole at each end of the crack, calk the crack or put a patch over it.

Q. If the water in the boiler is allowed to get too low what may be the consequence?

A. Burn the top of the combusting chamber and the tubes, and perhaps cause an explosion.

Q. If the water were to get too high in the boiler what then?

A. It would cause priming and maybe cause the cylinder head to break.

Q. What would you do in case the boiler was to foam and carry the water over in the engine?

A. Open my surface flow and slow down my engine.

Q. How would you line up an engine?

A. Remove all parts except the cylinder and crank shaft, strike a line from the top of the cylinder head to the bottom of the crank pit, put the engine on top centre, take the centre of the crank pin, take the centre of the top of the cylinder, the centre of the bottom of the stuffing box, then put the engine on the bottom centre, and if you find it comes the same your engine is in line. Then line your guides.

Q. Where is most pressure on a flat-bottom boiler?

A. On the bottom with the steam pressure and weight of the water.

Q. What is the difference between a high-pressure engine and a low-pressure engine?

A. The high-pressure engine exhausts against 15 pounds of the atmospheric pressure while the low-pressure engine exhausts in a condenser with an air pump attached which relieves that pressure.

Q. What is vacuum?

A. It is a space avoided of all pressure.

Q. How would you place the cams on a shaft?

A. Ninety degrees ahead of the crank or $\frac{1}{4}$ diameter.

Q. How would you set cut-off valves?

A. Place the engine on the top centre, place the valves on the cut-off stem, run the valves up until they cover the top and bottom port, then the valve is square; then pry the engine down to where you want to cut-off, run your cut-off valves up until they cover the ports, and so on to balance the stroke.

Q. How would you set main valve of an engine?

A. Place the engine on the top centre, put the links in the head motion, give the valve the proper lead, then reverse the links in the backing motion on the same centre, and if the lead is the same, the valve is square; place the engine on the bottom centre and do the same and the valve is set.

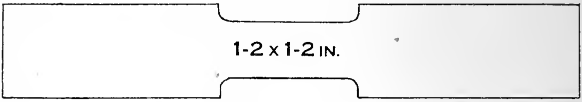
Q. How far is the bottom gauge cock above the crown sheet or tubes in the boiler?

A. From four to five inches.

Q. How do you determine the tensile strength of a boiler?

A. Tensile strength of a boiler plate means the resistance which a piece of metal offers to being torn asunder in the direction of the line of fiber; for instance, when we say that a certain boiler plate has tensile strength of 50,000 pounds we mean that it takes 50,000 pounds of force or weight to tear asunder, or entirely separate, a piece of metal just one inch square of section. There are certain methods by which tensile strength and ductility are found, and, furthermore, there are certain methods which each bear toward the other, which is important for engineers to know. Let us look into this for a few moments. In regard to determining the tensile strength of a strip of the plate cut from a boiler to be tested, it is cut off to a certain length and width, and is governed by the thickness of the plate. It is not the intention here to go into minor details. In determining the tensile strength the strip is carefully measured in all directions and the result noted after it is placed in a testing machine and subjected to a force sufficient to break asunder, such force being recorded by the machine; then the calculations are made in the following manner. Let us assume that we have a test piece which at the point where the fracture is to take place, is $\frac{1}{2}$ inch wide and $\frac{1}{2}$ inch thick. Now to find the area, as per requirements of the foregoing rule, we must multiply the width by the thickness, which is $.5 \times .5 = .25$ area at point of fracture. Let us also

assume that the strain at which our test piece parted is 15,000 pounds, therefore 15,000 ÷ .5 × .5 = 60,000 pounds tensile strength per square inch.



Half inch thick half inch wide.

.25)15,000.00(60,000 *tensile strength*
150

What Advantage Does Steel Have Over Iron?

First, it is lighter; second, it is stronger; third, its condensing power is higher; for instance, it will evaporate 25 per cent. more water with the same amount of fuel in a given time. Steel boilers are more free from corrosion than iron on account of the density and compactness of the material.

Construction of a steam gauge.

The principle of a dial steam gauge is that the pressure may be indicated by means of a pointer in a divided dial similar to a clock face, but marked in division, indicating pound pressure per square inch above the atmospheric pressure, and shows the ordinary style of gauge, which consists of an elliptical tube connected at one end to a steam pipe in connection with the boiler pressure.

Q. What causes pitting in a boiler?

A. An acid which generally comes from animal oil.

Q. How should pitting in a boiler be treated?

A. First it should be scraped and cleaned with a strong solution of soda or coal oil to remove grease and acids and then covered with a thin coat of white zinc to fill up the pit holes to prevent further pitting.

Q. What benefit is derived from circulation of the water in a Scotch boiler when the engine is stopped?

A. The boiler is kept at a more equal temperature, and contraction and expansion is not so great.

Q. Where is the most pressure on a boiler and why?

A. A boiler when filled with water, and when it has a steam pressure, contains the most at the bottom, because the bottom has the weight of the water plus the pressure of steam.

Q. What should be done if a boiler head were to crack from one tube to the other?

A. One or more holes should be drilled into the crack and tapped out, and in those holes, plugs should be screwed and tapped and calked.

Q. Where would you look for pitting in a stationary boiler?

A. Most generally on the tubes, and sometimes pitting takes place on the water line or a little below.

Q. Where would you look for pitting in a marine boiler?

A. The fire line of the furnace, also around the combustion chamber, and the back head and in some Scotch boilers it is known to pit on the bottom of the boiler.

Q. In what direction is the steam pressure in a boiler exerted?

A. In all directions.

Q. Why is the butt joint of a boiler the strongest?

A. The butt joint is the strongest because it is a true circle.

Q. Why are the short screw stay bolts turned smooth in the centre?

A. They are turned smooth in the centre to prevent corrosion, as a smooth surface does not corrode as quickly as it does in rough stays.

Q. Why is a large factor of safety used for boiler stays?

A. A large factor of safety is used to allow for corrosion or eating away of the metal.

Q. What are the four principal points to consider in cylinder boilers for carrying high steam pressure?

A. First, the tensile strength; second, diameter; third, pitch and size of rivet; fourth, thickness of plate.

Q. Will a boiler 72 inches in diameter $\frac{3}{8}$ thick made of iron stand as much pressure as a boiler 48 inches in diameter and $\frac{3}{8}$ thick?

A. No.

Q. Why?

A. Because the pressure in a large boiler has more surface and will not allow it. It is the same as a long bar of the same thickness. It takes less to break the small one than the short one.

Q. How do you ascertain if your shaft is out of line?

A. Take the coupling bolts out of the coupling, and if the coupling faces up square the shaft is in line.

Q. How is it arranged sometimes to give a boiler more power?

A. By using a forced draft.

Explain the Thermometer

A thermometer is based on the change of volume to which bodies are subject with the change of temperature. A thermometer is filled with air, water, or mercury. It consists of a tube of glass formed with a bulb at the bottom filled with mercury, and it is graduated in numbers: blood heat, 100°; temperature, 52°; freezing, 32°. Boiling-point is divided into 180°, freezing being 32° and boiling 212°.

Q. Name the different kinds of compound engines?

A. Tandem cross, high-pressure, low-pressure, triple expansion, and quadruple expansion.

Q. How much larger is the low-pressure cylinder than the high-pressure cylinder?

A. Twice the area of the high-pressure cylinder.

Q. How is the horse power of a non-condensing compound engine found?

A. By finding the area of each cylinder separately, then adding them together and dividing by two to get the average. Then the mean effective pressure is found by adding the two mean effective pressures together and divide by two less the back pressure.

Q. What is a surface condenser?

A. It is where the exhaust steam flows around cold tubes that the circulating water passes through condenses the steam into water. It drops to the bottom of the condenser, is then taken out by an air pump and pumped back to the boiler.

What is a Jet Condenser

A. It is a chamber in which the exhaust is compelled to pass through a spray or a jet of cold water, and after condensed it mixes with the injection water into a hot well and from there some is pumped in the boiler and the balance is pumped overboard.

Q. Which is the most economical of the two, a jet or a surface condenser?

A. The jet for stationary work, because it uses less water.

Corliss Engine

Q. How is a Corliss engine valve set and adjusted?

A. First take off the back caps of all four valve chambers. Lines will be found on the end of the chambers which show the working edge of the ports and valves and the lap and lead. The wrist plate central located between the four valves has three lines on top of its hub edge, and correspond with the single lines on top of the brackets. They show the central and two positions of four valves. The valve is next adjusted by unhooking the reach rod from the wrist-plate pin, then hold the wrist plate

in the central position, and by means of right and left thread rods, adjust each valve singly. Set the steam so they will have $\frac{1}{4}$ inch lap for a 10-inch cylinder and $\frac{1}{2}$-inch lap for 32-inch cylinder. Exhaust valves should have $\frac{1}{16}$ lap for 10-inch cylinder, $\frac{1}{8}$ for 32-inch cylinder. For high-pressure no lap-condensing engine gives nearly double the lap.

Q. After making those adjustments what is to be done?

A. The dash pot rods are adjusted by turning the wrist plate to its extreme of travel and adjust each rod so that when the rod is down as far as it will go the stud on the valve arm will just clear the latch on the latch hook.

Q. If the rod is too long or too short what is to be done?

A. If the rod is too short the hook will not drop in; the valve will not open.

Q. How much salt would you allow the water to get in a boiler with a jet condenser and surface condenser?

A. Not over $1\frac{1}{2}$ to $\frac{2}{32}$.

Salinometer

A salinometer is a glass or a metal instrument by which the density of water is ascertained. It consists of a weighted bulb, to which is attached graduated steam, and its action is to indicate the amount of salt held in solution in the water by floating higher or lower—higher for density and

lower for freshness. Some are graduated into 33 rods and some to 32 rods, each representing about five ounces of salt to a gallon of water. Care must be taken to use the salinometer at the temperature for which it is marked, as the density of fluids vary in proportion to their temperature, 200° being the usual temperature of the water in which these instruments are tested, so that they may be used almost immediately on the water from the boiler.

Sea water contains $\frac{1}{32}$ part salt—that is, if 32 pounds of sea water were evaporated one pound of salt would remain. $\frac{1}{32}$ is for this reason taken as the unit by which to measure the density of the boiler water. If the water in the boiler has the same amount of salt in it as sea water, we say it has one degree of salt; if it contains twice as much salt per gallon as sea water, then it has two degrees of salt —that is, $\frac{2}{32}$ salt; five ounces of salt to a gallon. Do not let the water in the boiler get over $1\frac{1}{2}$ or $\frac{2}{32}$ salt in the boiler.

Q. Could you make a salinometer if you had none?

A. Yes; take a bottle and weight it down so it will float upright, then take some fresh water and put it on some hot coal and boil it to 190° or 200°, then place the bottle in the fresh water and mark the bottle at the fresh water line; then take some salt water out of the sea and boil it 190° or 200°; then you will find the bottle will raise $\frac{1}{32}$, the difference between fresh water and salt water.

Indicator

Q. What is the use of an indicator on an engine and what information does it give?

A. It shows the expansion of steam in the cylinder, also if the valves are properly set and adjusted.

Q. How many lines does the indicator card show when steam is against the indicator piston, also when turned off?

A. Seven lines: six with steam—namely, compression, admission, steam, expansion, release, and exhaust.

Q. When steam is turned off the indicator, the atmosphere line is drawn, making the seven, are there any other lines drawn on the card, and if so, when?

A. Yes, two, the vacuum and clearance lines. They are drawn after the card has been laid out on a flat surface board.

Q. How are cards measured and calculated to find the M. E. P.?

A. By dividing the length of the card into 10 equal parts by drawing perpendicular lines in regular order called ordinates from the steam end to expansion line down to the atmosphere line.

Q. After the card has been properly laid out what should be done?

A. Take a strip of paper $\frac{1}{4}$ inch wide and about 12 inches long. Lay it alongside of the first ordinate, mark the length, then lay the strip up to the

second ordinate so its length will be added to the first, and so on until all the 10 ordinates will be in one straight line. Then take total measurement in inches. Suppose the total length was 9 inches long and the spring was 30 pounds, how is the M. E. P. found?

A. The card is 9 inches long × by the spring 30 pounds divided by 10 ordinate.

```
                30 spring
                 9 length of card
                ——
ordinate 10)270(27 mean effective pressure
               20
               ——
                70
                70
                ——
```

Q. What is meant by M. E. P.?

A. It is the mean effective pressure of steam that is on the piston throughout the stroke less the back pressure.

Q. How is the horse power of an engine found when the M. E. P. is known?

A. Find the area of piston × by M. E. P. × by piston speed in feet per minute and divide by 33,000. This equals the horse-power.

A. Diameter of cylinder, 20 inches; stroke of engine, 20 inches; mean effective pressure on piston, 27 pounds; revolutions per minute, 120.

Example to Find the Horse-Power

```
   20 in. stroke                 20 diameter of cylinder
   20                            20
   —                            ———
   40 inches                    400
   120 revolution
   ———                         .7854
   800                            400
  40                          ———————
  ———                         314.1600 area of piston
12)4800(400 feet per minute         27 M. E. pressure
  48                          ———————
  —                           21991200
                              6283200
                             ————————
                             8482.3200
                                   400 feet per minute
                             ———————————
                 33000)3392928.0000(102.8 horse-power
                       33
                       ———
                        92
                        66
                        ———
                        269
                        264
                        ———
```

Another Way to Get the Horse-Power

To get the horse-power of indicator card, first get the square inches in the cylinder, then multiply that by .7854 to get the area, then multiply the area by twice the stroke in feet multiplied by revolution and divide by 33,000; that will give the constant; then count the card up to get the M. E. P. We will say the M. E. P. is 40 on the piston. Multiply half the card by the constant, half the card is 20 pounds, that will give the horse-power of the

engine and deduct the atmospheric pressure from the horse-power. We will take the diameter of the cylinder 18 inches, 18-inch stroke 100 revolutions per minute, allowing 33,000 pounds per horse-power.

EXAMPLE

18 stroke of engine
18
—
36
100 revolution
—
12)3600(300 feet
36
—

18 diameter cylinder
18
—
144
18
—
324 square of cylinder

.7854
324
—
31416
15708
23562
—
254.4696
300 feet per minute
—
33,000)76340.8800(2.31 constant
66000
—
103408
99000
—
44088
33000
—

2.31 constant
20 half card
—
46.20

This example is to get the M. E. P. of card on piston mean effective pressure on piston 40.

Horse power is 46.20.

Q. If at sea and the water in the boiler was gaining where would you look for the trouble and what would you do?

A. Try the water in the filter box or hot well for salt, if I found the water salt I would try all valves that were attached to the condenser from the sea, if I found them all right I would see if the discharge from the air pump was taking in water as it sometimes does when a ship is rolling deep and if the water still continues to gain in the boiler I would give each boiler a little blow and when in port take off condenser heads and plug tubes.

Q. Why is too late admission loss of power?

A. Too late admission is a loss of power because the piston has travelled a part of the stroke before the steam has attained to its full pressure. Late admission means that the valve has no lead.

Q. If the high pressure of a compound engine was on the centre, how would you start it?

A. Admit steam to the low pressure cylinder.

Q. How much lap should a piston valve have?

A. About the same as a slide valve has.

Q. Which will have the most lap exhaust or piston valve?

A. There is not any difference.

Q. From which end of the cylinder does the piston travel the faster?

A. It always travels the faster on leaving the head end of the cylinder on account of the weight of the connecting rod and piston.

Q. How would you run a tandem compound engine if either high or low valve stem should break?

A. If high valve stem should break, take out the valve and run with a reduced boiler pressure; if the low valve stem should break, take out the valve and run as a simple.

Q. If a crank broke on the high pressure side of a cross compound engine how would you run it?

A. Take out valve, block piston and crank, and run with a reduced pressure.

Q. How would you run if crank broke on low pressure side?

A. Take out low-pressure valve, block the piston at its crank, and run as above.

Q. How would you set the valves on a Corliss engine to run high pressure?

A. Set the steam valves with $\frac{3}{8}$ of an inch lap; exhaust valve line and line when the wrist plate was central and hook in, and make further adjustment with the indicator.

Q. How would you set them to run on a condenser?

A. With a little more lead and a little earlier compression.

Q. What advantage do we get in having an eccentric on a Corliss engine?

A. Greater range of cut off.

Q. Should there be two wrist plates?

A. It's not necessary.

Q. Why do we give more lap on the steam valve of a large Corliss engine than we do to the small one?

A. To get earlier compression.

Q. How would you give a Corliss engine more lead without giving it more compression?

A. Shorten the steam link.

Q. How would you give Corliss engine more compression?

A. Advance the eccentric, making the required change or lengthening steam links.

Q. Does the eccentric set ahead or behind the crank of an automatic engine and why?

A. If the engine is to run ahead, the eccentric sets behind the crank, because it is a direct motion with the piston and indirect from the governor.

Q. What is a cross compound engine?

A. One in which the cylinders set side by side and with cranks usually at right angles to each crank.

Q. What is a tandem compound engine?

A. One in which one cylinder seats ahead of the other on the same piston rod and connected to the same crank.

Q. Why is a compound engine more economical than a simple engine, when the steam pressure is the same?

A. Smaller ports and less condensation.

Q. If you were at sea and your high-pressure engine became disabled beyond repairs, how would you proceed?

A. Disconnect your high-pressure engine and run with your after engine.

Q. Describe just what you would do upon entering your engine room in the morning, the plant being shut down under fires banked through the night?

A. The first duty of an engineer when entering his plant at any time is to ascertain how the water in the boiler stands; he should open the gauge cocks and note what came from each in turn, then open the cocks or valves connected to the water glass gauge, and note the water line there shown; he should also blow the water column out in case any sediment may have choked any of the passage which would be liable to give a false impression as to the actual quantity of water contained in the boiler. Should the water be found at the correct height, he may now proceed to haul his fires down; then when the boiler has made about 25 or 30 pounds of steam, you should give your boiler a good blow down.

Q. How would you find travel of a valve having a steam lap of $\frac{3}{4}$ of an inch and a maximum port opening of $1\frac{3}{8}$ inches?

A. The maximum port opening at the head end plus the lap at the head plus lap at the crank end $1\frac{3}{8} + 1\frac{3}{8} + \frac{3}{4} + \frac{3}{4} = 4\frac{1}{4}$ the required travel of the valve. It is well to give practical methods. The travel of any valve is obtained from the eccentric by subtracting the thin part of the eccentric from the thick part of the eccentric, is termed the throw of the eccentric.

Q. Can a proper vacuum be formed?

A. No, about 9 to 11 per cent. of the atmospheric pressure, which is 14.7 pounds per square inch.

Q. What will vacuum do?

A. It will raise water 33 feet, providing all pipes and connections are air-tight.

Q. Name the different things that will affect the vacuum in a condenser.

A. Extra feed valves being open after tank is empty, circulating pump running too slow, condenser being too small, dirty tubes, low-pressure piston packing too loose in stuffing-box, air-pump valves or piston packing bad, or any leak that will admit air in condenser.

Q. If you were compelled to change from surface to a jet condenser, how would you proceed?

A. Stop circulating pump if it is working; start the engine and open the jet valve on condenser slowly, until I have it open enough to form twenty inches of vacuum or more.

Q. What would be the result if you opened the jet valve too much?

A. You would admit too much water to the condenser, therefore putting too much load on the air-pump.

Q. If you were running jet condenser and you stopped, what would you do?

A. Shut off the injection valve to condenser.

Q. Why would you shut off injection valve to condenser?

A. To hold the vacuum in the condenser as long as possible and not to flood the condenser.

Q. Explain how shutting off injection valve on the condenser would hold the vacuum?

A. As vacuum is a space void of all pressure and you leave any valve open that will admit air or

water, you will have atmosphere or water pressure in your condenser.

Q. If you had atmosphere or water pressure in your condenser how would it effect the engine starting?

A. It would cause the engine to start bad, and put on extra load on the air-pump and discharge pipe; it has been known to cause a break down.

Q. Why is a condenser used?

A. To relieve the engine of back pressure and maintain fresh water for the boiler.

Q. If you were at sea and your circulation pump became disabled, how would you get into port?

A. Run jet condenser; if not, run high-pressure.

Q. If your air-pump were to break down and you had no other pump to take its place, what would you do?

A. Keep the circulation pump running, take off bottom plates on condenser, let the condensed water run in the bilge, and pump it out.

Q. If you had no water jet on your condenser, how would you make a jet condenser out of a surface condenser?

A. By taking out enough tubes to supply the condenser with water to condense steam and use the sea cock for the jet valve.

Q. Why will a pump refuse to lift hot water?

A. A pump will refuse to lift hot water because the vapor will rise and prevent a vacuum from being formed, and consequently an unbalanced condition of pressure cannot exist which is necessary to cause

the water to flow up to the pump, therefore if you want to pump hot water place the pump so that the hot water will run to it.

Evaporation of Water and Coal Burn

Q. How many pounds of water would you expect a pound of coal to evaporate, and how many pounds of water required per hour for triple expansion engine?

A. A good boiler will evaporate ten pounds of water under ordinary circumstances, but it depends upon the efficiency of the boiler, the quality of coal, the temperature of the feed water and the temperature of which steam is generated. A triple expansion engine requires eleven or twelve pounds of water per hour.

Q. How much water will a pound of coal evaporate?

A. The average is about one gallon per pound of coal.

Q. What is the consumption of coal per square foot of grate surface in a steam boiler?

A. With natural draft about ten to twelve pounds per square foot of grate surface.

Q. What is the water consumption in pounds per hour indicated horse power?

A. From 25 pounds to 60 pounds.

Q. What is lead on a valve?

A. Lead is the distance or amount that the valve comes short of covering the port when the piston is at the beginning of the stroke.

Q. How many kinds of lead are there?

A. There are two kinds outside or steam lead and inside or exhaust lead, outside or steam lead is the distance that the outside or steam side edge of the valve comes short of covering the port when the piston is at the beginning of the stroke, inside or exhaust side edge of the valve comes short of covering the port when the piston is at beginning of the stroke.

Q. How do you give an engine more lead?

A. By advancing the eccentric on the shaft.

Q. What effect has too much lead on an engine?

A. It causes the engine to pound also forms too much cushioning.

Q. What is the use of lap on a valve?

A. Give the engine compression and also to work the steam expansively.

Q. What is the use of a valve?

A. It regulates the flow of steam to and from cylinder.

Q. What use is a link on an engine?

A. To cut off the steam at different parts of stroke.

Q. How much heating surface is allowed per horse-power in a boiler?

A. Twelve to fifteen square feet.

Q. How do you find the proper size of a safety valve to be placed on a boiler?

A. Three square feet of grate surface is allowed for one inch of area of valve.

Q. How hot can you get water under atmospheric pressure with exhaust steam?

A. 212 degrees.

Q. What is meant by atmospheric pressure?

A. The weight of the atmosphere.

Q. What is the weight of the atmospheric pressure at the sea level?

A. 14.7 pounds.

Q. How many pounds of water can be evaporated with one pound of the best soft coal?

A. From 7 to 10 pounds.

Q. Why do we condense steam?

A. To form a vacuum and so destroy the back pressure that would otherwise be on the piston and thus get more useful work out of the steam.

Q. What is meant by horse-power?

A. Horse-power is equivalent to raising 33,000 pounds one foot high per minute.

Q. What is meant by a triple expansion engine?

A. A triple expansion engine has three cylinders using the steam expansively in each cylinder.

Q. What is meant by using steam expansively?

A. When the steam is admitted at a certain pressure, is cut off, and allowed to expand to a lower pressure.

Q. What would you do if you were to knock your top cylinder head out of your compound engine beyond repairs?

A. Block the steam ports so as not to admit any steam on the top end of the piston, reduce steam pressure and proceed. If it sticks on the centre put a liner under the eccentric rod so as to admit more steam on the bottom of the piston.

Q. What would you do if you broke a low pressure connecting rod on compound engine?

A. Use the high-pressure connecting rod and put it in the low, then take high-pressure valve out, so as to let steam pass over into the low-pressure valve, then let the high-pressure piston down to the bottom of the cylinder, then reduce steam pressure.

Q. What is the object of putting zinc plates in a boiler?

A. It causes a galvanic action and the acids in the water act directly in the zinc plates instead of on the boiler plates and shell.

Q. How often should the zinc plates be renewed?

A. As often as they are corroded and eaten away.

Q. To find the scale of the spring for taking a diagram from high-pressure cylinder?

A. Divide the gauge pressure by $2\frac{1}{4}$.

Q. In a triple-expansion engine with second cylinder doing much more work than low pressure, how can your cut off be best adjusted in either cylinders to balance load between cylinders?

A. By shortening the cut off on the low-pressure cylinder thus increasing the back pressure on intermediate reducing the pressure on it, also the back pressure on the high-pressure cylinder.

Q. What is the effect on receiver pressure of cutting off later in first cylinder?

A. The receiver pressure will be raised and the engine will perform more work. The low pressure piston in this case will perform more work than the high pressure piston on the former. The pressure

is increased, while on the latter the back pressure, the cut off, and has to be regulated for both cylinders to make them perform even share of the work.

Q. Name the bad features of the keel condenser?

A. Two bad features of the keel condenser are that the water will not flow good to the air pump, and if the climate is cold enough to bring the water on the outside of the condenser down to a freezing point the fresh water in the condenser will freeze solid, and that will be an extra expense.

Q. Can the heat of steam be raised to a very high temperature?

A. Steam can be heated to nearly a red heat, but not while it is held in contact with water.

Q. How is it arranged sometimes to give a boiler more power?

A. By using forced draft.

Q. Are holes drilled or punched in a boiler?

A. They are drilled in a boiler.

Q. What would be the result of incorrect length of eccentric rod?

A. Too much lead on the rod or not enough lead.

Q. The question is very often asked why they use a piston valve?

A. You take a 10 inch piston valve, the area is 78 inches with 120 pounds of steam would be 78 inches × by 120 = 93.60 pounds per square inch of area on piston valve, take a flat valve 14 inches wide and 24 inches long would be 24 × 14 inches 3.36 square inches × by 120 pounds of steam = 403.20; the flat valve has 309.60 pounds more pres-

sure than a piston valve; the piston valve has less friction by 309.60 pounds.

Q. Which is the best way to run a stationary engine, over or under?

A. Over, because the pressure of the crosshead and the main shaft is downward on the foundation instead of up against the guide or caps.

Q. The question is often asked what is the best way to set a piston valve?

A. Place the engine on top or bottom centre, place the piston valve in its place, then give the piston valve the full opening of the exhaust and the piston valve is set nearly correct.

Dynamo Electric Questions

A dynamo is a machine by means of which mechanical energy is converted into electric energy. A dynamo electric generator or dynamo electric machine is ordinarily constructed as follows: Parts: armature, the field magnets, the commutator, and collecting brushes. A dynamo is classified under two headings: first, direct current generator; second, alternating current generator. The direct current generator is divided into series wound machine, shunt wound machine and compound wound machine; and the alternating current are classified with respect to the character of the current they develop. In this case it may be said that there are single-phase machines and two-phase machines and three-phase machines.

Among alternating current generators are found forms of construction of a space character in which neither the armature wire nor the field being produced. The series wound dynamo is generally employed for a system of electric lighting in which a constant current is necessary, such as high-tension arc lighting. For instance the function of this type of generator is to provide a current of 10 or 12 amperes and a voltage that is capable of being adjusted by special means to suit the number of lamps in use. The arc lamps are connected in series. Each lamp takes the same amount of voltage. If twenty or thirty lamps are connected twenty or thirty times the volts required for one lamp is the total voltage to be generated and would equal 20 × 50 or from 1000 to 1500 volts. Arc lamps as now used may be of the open or closed arc type; by this is meant that the carbon either burns in the open air, lasting only about eight or ten hours, or enclosed in small globe. Each lamp takes 50 volts if of the open air type; if of the closed globe type, each lamp will take about 80 volts. The dynamo must be able to automatically raise or lower its voltage when the lamps are turned on or off. When more lamps are added to the line, more voltage will be required. In fact, as much more as there are extra lamps. When lamps are cut off, less voltage will be required in proportion to the number of lamps. For instance, if ten of the closed globe type are added to the circuit of a series wound dynamo by simply turning them on, 10 × 80 or 800

volts more must be sent into the line; on the other hand, if 10 lamps are cut out 800 volts less in the line will do.

Sparking on a Dynamo

Sparking may be caused by too great a load on the dynamo or by wrong position of the brushes. One brush may not be opposite the other in a two pole machine, or the brushes may not be properly adjusted on the commutator if they belong to a multipolar machine On a four pole machine they should be 90 degrees apart; on a six pole machine, 60 degrees apart. The simplest way of getting the correct distance between brushes is to count the commutator bars and divide them by the numbers of poles of the generator. Sometimes sparking at the commutator is caused by the bars being loose; or the mica and the bars may be projecting beyond the brushes. In general the difficulty is frequently found in the more rapid wearing away of the copper bars before the mica itself has worn down. The mica is harder than might be expected, and the brushes do not affect it. Sandpapering the commutator is of little or no use; the only remedy is the turning down of the commutator. The best way to do this is by a lathe or by a special commutator turning device.

Q. How do the alternating and the direct current generators differ?

A. The direct current generator uses a commutator in order to send out a current. Following always in the same direction alternating current generators use collecting rings, which permit all the alternations generated within the armature to occur outside in connecting circuits.

Q. What reverses the direction of a current in a conductor?

A. The fact that it has being moved past a north pole or a south pole. The electro-motive force tends to send a current in one direction when the conductor passes a north pole and in the reverse direction when it passes a south pole.

Q. What is the action of the commutator and brushes?

A. To permit all positive impulses to flow into one brush or set of brushes and all negative impulses to flow into the other brushes or other set of brushes.

Q. What causes heating a commutator?

A. Bad contact between the brushes and the commutator, a small commutator, too much pressure from the brushes, or a brush of too great a resistance.

A brush should never be lifted off the commutator while the dynamo is running. Every binding screw should be examined, and if necessary tightened every day, as they are liable to be loosened by a slight jar of the dynamo.

It is advisable to run a new dynamo a few hours or even a day without any load on in order to have everything in proper working order before putting on the load, which should be done gradually.

Starting and Charging an Ammonia Compressor

As each type of ammonia compressor has its own feature of construction, each particular machine will require special care and laid down to suit all cases. There are, however, some general principles which are attached to all types based on the compression system. Before charging an empty machine with ammonia all air must first be expelled, this is done in various ways, one method often used is to pump the system full of gaseous ammonia and shut the engine down, allowing the water to flow in the condensor until all the ammonia in the system is condensed, the liquid ammonia being heavier will drop to the bottom of the system, the valve can then be opened at the highest part of the system and the pressure of the ammonia gas will indicate when to shut off the valve, the system can then be allowed to stand six or twelve hours, and the valve again opened; if there is any air remaining in the system it will be driven out when the valve is again opened. Before charging the system it can be thoroughly tested by working the compressor and permitting air to enter at the suction through the special valve provided for that purpose, and it should be perfectly tight at 200 or 250 pounds per square inch, and should be able to hold that pressure without loss while testing the system under air pressure. It should be carefully and thoroughly cleaned of all dirt and moisture by blowing out. In some cases it is impossible to get

rid of all of the air from the plant by means of the compressor, therefore, it is advisable to insert the requested charge of ammonia gradually; sometimes from 60 to 70 per cent. of the fuel charge is put in, and the air remaining in the system is allowed to escape through the purging cocks with as little loss of gas as possible; subsequently an additional quantity of ammonia, once or twice a day, is inserted until all the air has been displaced and the complete charge has been introduced. To charge the machine the drum of ammonia is connected through a suitable pipe to the charging valve. The machine should be run at a slow speed when sucking the ammonia from the tank, with the discharge and suction valve wide open. When one of the tanks is emptied the charging valve is closed and another tank placed in position, and the process continued until the machine is charged for work, when the charging valve can be closed, and the main expansion valve opened and regulated. A glass gauge upon the liquid receiver will show when the latter is partially filled and the pressure gauge, as well as the gradual cooling of the brine in the refrigerator and the expansion pipe, being covered with frost, will indicate when sufficient ammonia to start working has been inserted. The machine having been started and the regulating valve opened the temperature of the delivery pipe should be carefully noted, and if it shows a tendency to heat, then the regulating valve must be opened wider; while if it should become cold, the valve must be slightly closed, the

regulation or adjustment thereof being continued until the temperature of the pipe is the same as the cooling water which leaves the condenser if the charge of ammonia is insufficient, the delivery pipe will become heated. Even the regulating valve is wide open. Among the signs which denote the healthy working of the plant, beside the fact that it is satisfactorily performing its proper refrigerating duty, the vibration of the pointer of the pressure and vacuum gauge which clearly makes every stroke of the piston, the frost on the exterior of the ammonia pipes, the liquid ammonia can be distinctly heard pouring through the regulation valve in a continuous stream, and the difference in temperature between the condenser and the cooling water and the refrigerator and the brine.

Q. Does the temperature of steam at ordinary pressure contain heat enough to ignite wood?

A. Not without the intervention of some other substance, such as linseed oil, greasy rags, or iron turnings.

Q. How do you explain that?

A. Because we know that the temperature of superheated steam is only about 400° Fahrenheit, and it requires more than double that temperature to ignite wood.

Q. How is the power of steam engine expressed?

A. In a horse-power.

Q. What is a nominal horse-power?

A. 33,000 pounds raised one foot high in one minute.

Q. Why is it that 33,000 pounds raised one foot high in one minute is adopted as a standard for a steam engine?

A. Before the introduction of the steam engine it was found by experiment that with the average horse the best speed for work was at the rate of $2\frac{1}{2}$ miles per hour, and at that rate of speed a horse could raise at perpendicular a weight of 150 pounds 220 feet high in one minute, which is equivalent to 33,000 pounds raised one foot high in one minute, and was taken by Watts as a standard for a horse-power, and is universally received as such. For instance, an engine of 60 horse-power can raise 33,000 pounds one foot high in a second or an engine of 420 horse-power would raise 33,000 pounds one foot high in $\frac{1}{7}$ of a second.

Q. The question is often asked why is it necessary to make the longitudinal seams so much stronger than the transverse or girth seam.

A. The reason is that the strain on the longitudinal seam is twice that of the transverse seam. In some types of boilers it is more than twice, for in the return tubular or a boiler having tubes and stays from head to head they relieve the transverse seam while the longitudinal seam has the full load to carry. On the transverse or girth seam the pressure would be the area of the head being required of the diameter $2 \times .7854$ by the total pressure strain this pressure acts endwise along the boiler tending to pull it apart, and it is withstood by the plate of the boiler, and where this comes together at the girth seam

the length of each girth seam is the same as the circumference of the boiler—that is, it is equal to .7854 × by diameter squared × by the pressure divided by 3.1416 × by diameter, since 3.1416 is exactly 4 times .7854, we find from the above calculation that the strain on the girth seam per inch of its length is

$$\frac{\text{diameter} \times \text{by pressure}}{4}$$

If a two inch pipe discharges 3600 gallons of water per minute, what is the velocity in feet per second?

```
one minute 60)3600(60
               360         60)60(1
               ---            60
    one foot per second       --
```

Rule for a Pump

A pump with a water end 5 inches in diameter and the steam end 6 inches in diameter with 70 pounds pressure the pump is pumping against 100.8 pounds. Suppose you wanted to change the water end of the pump to pump against 157.5 pounds per square inch, what would be the diameter of the pump end.

Diameter of pump is 5 × 5 = 25 square inches × 100.8 pounds = 2520.0 ÷ by the pressure the pump is to pump against which is 157.5 = 16 and the square root of 16 = 4 = diameter pump.

```
diameter 5          100.8
         5             25
        --          -----
        25           5040
                    2016
                   ------
             157.5)2520.0(16
                   1575            16(4
                   ----            16
                    9450           --
                    9450
                    ----
             diameter of pump is 4 inches
```

Donkey Pump

To find the number of gallons a pump will pump allowing 231 cubic inches to a gallon single acting pump number of strokes per minute 100 diameter of the pump $4\frac{1}{2}$. Length of stroke is 8 inches.

```
           4.5 diameter of pump
           4.5
           ---
           225
          180
          ----
         20.25
         .7854
         -----
          8100
         10125
        16200
       14175
      ---------
      15.904350
              8 inch stroke
     ----------
     127.234800
            100 revolutions
     -----------
231)12723.480000(55.08 number of gallons per minute
    1155
    ----
     1173
     1155
     -----
      1848
      1848
     -----
```

Donkey Pump

Take a pump with the steam end 6 inches in diameter, 60 pounds of steam, the pump end is 4 inches in diameter, what pressure per square inch will this pump pump against?

```
                      6 steam end
                      6
                     --
                     36
                      60 steam pressure
                    ----
square of the    16)2160(135 pounds this pump will pump
  pump end          16             against
                    --
                     56
```

Take the same pump to find the height the pump will pump water in feet. Take a constant of 2.305 × by the pressure the pump will pump against that will give the height the pump will pump water in feet.

```
  2.305
    135 the pump will pump against
  -----
  11525
  6915
 2305
-------
311.175
```

This pump will pump 311 feet high.

THE HORSE-POWER OF A PUMP

What is the horse-power of a pump with the following dimension: Diameter of pump 10 inches, revolutions per minute 80, 156 pounds total head pressure per square inch on pump, stroke is 28 inches.

```
                .7854
                    100 square of pump
                -------
                78.5400
                     28 stroke
                -------
                6283200
               1570800
              ---------
              2199.1200
                       80 revolution per minute
one cubic     -----------
  ft.   1728)175929.6000(101.8 cubic feet

                          101.8 cubic feet
                           62.5 pounds to cubic foot
                          -----
                           5090
                          2036
                         6108
                        -------
                        6362.50
                            156 total pressure on pump
                        -------
                        3817500
                       3181250
                       636250
                      ---------
             33,000)992550.00(30.
                    99
                    --
                    25
```

This pump is 30 horse-power and a little over.

Donkey Pump Rule

If you were going to test your main boiler in your ship to put 120 pounds of cold water pressure on your main boilers, and if you had a donkey boiler, what pressure of steam would you carry on your donkey boiler to put 120 pounds of cold water pressure on your main boilers with a pump 6 inches in diameter and the steam end 10 inches.

```
                     6 water end
                     6
                    --
                    36
                    120 cold water pressure
                    ---
                    720
                   36
                   ----
square of pump  100)4320.(43.2 it would take 44 pounds
  end              400
                   ---
                    320
                    300
                    ---
                     200
                     200
                     ---
```

Q. What is the horse power of a boiler?

A. The evaporation of 30 pounds of water per hour from feed water 100° Fahrenheit into steam at 70 pounds' gauge pressure has been adopted as the horse-power of a boiler.

To find the thickness of a casting to stand a certain pressure when you have the inside dimension and the steam pressure. We will say that the casting is 20 inches inside diameter, 95 pounds of steam.

Example

$$\frac{95 \times 20}{4{,}000} + 0.6$$

95 steam pressure
20 inside diameter

```
constant—4,000)1900.000(.475
               16000
               -----
                30000
                28000
                -----
                 20000
                 20000
                 -----
```

```
 .475
 0.6
 -----
1.075 thickness = 1 1/16
```

To find the pressure on a guide slipper area of piston × by total pressure × by length of crank pin, divided by the area of the guide slipper × by length of the connecting rod.

To Find the Pressure on Crank Pin

Area of the piston × by total pressure divided by the length of the crank pin × by diameter of crank pin.

To Find the Pressure on Thruss Bearing

First get the horse-power of your engine, we will say 175, revolutions 140, pitch of wheel is 5 feet; allowing 2240 pounds to a ton then multiply 175 × 33,000 = 5775000 ÷ 140 × by 5 = 700.

```
140        175 horse-power
  5         33,000
----       -------
700        525000
          525
         -------
   700)5775000(825000
        5600
        ----
         1750
         1400
         ----
          3500
          3500
          ----
```

```
2240)825000(3.69 tons on shaft
     6720
     -----
     15300
     13440
     -----
      18600
      17920
      -----
```

three tons and over half ton

Side Wheel Steamer

To find the number of revolutions that a steam engine has to make per minute with a paddle wheel 17 feet in diameter to make $17\frac{1}{2}$ miles per hour; allowing 6080 feet in one mile.

```
  3.1416                                  6080
     17 diameter                          17.5 miles
  ------                                 ------
  219912                                 30400
  31416                                 42560
  -------                               6080
  53.4072                              --------
      60 one minute           3204)106400.0(33 revolutions
  -------                                        per minute
3204.4320
```

Take the same example to find the number of miles it will make in 33 revolutions per minute.

```
 3.1416
    17 diameter wheel
 ------                                        33
 219912         53.4)6080.0(113                 60 one minute
 31416               534                       ----
 ------              ----               113)1980.(17.5
53.4072               740                   113
                      534                   ---
                      ----                  850
                      2060                  791
                      1602                  ---
                      ----                   590
    17.5 miles per hour                      565
                                             ---
```

How many miles will a ship travel per hour when the engine is making 80 revolutions per minute,

pitch of wheel 20 feet, allowing 20 per cent. for slip, allowing 5280 feet in a land mile.

$$\frac{80 \times 60 \times 20}{5280}$$

```
    80 revolutions
     60 one hour
   ----
   4800
      20 pitch of wheel             18.18
   -----                                20 per cent.
5280)96000( 18.18                  ------
             3.63                  3.6360
          ------
          14.55 miles the ship makes
```

If the pitch of a wheel is 16 feet, how many revolutions must it make to advance 10 knots per hour, a knot being 6080 feet?

$$\frac{6080 \times 10}{16}$$

```
                          6080 one knot
                            10 knots
                          ----
                       16)60800(38.00 revolutions
                          48
                          ---
                          128
38.00 revolutions         128
                          ---
```

If a ship has a wheel 18 feet pitch, 75 revolutions per minute, allowing 6080 feet in one knot, how many miles will the engine make, and what is the slip of the wheel; observation is 295 miles in 24 hours in one day?

18 ft. pitch
75 revolutions

90
126

1350
60 one hour

81000
24 one day

324000
162000

one knot 6080)19440000(319 knots by wheel
18240

12000
6080

59200
54720

319 knots by wheel
295 observations

knots by wheel 319)24.0000(7.52 slip of wheel
2233

1670
1595

750
638

Rule to find how far a steamer will run in six minutes, allowing 1760 yards in a mile, 175 revolutions, pitch of wheel 8 feet, not including the slip of the wheel, allowing 3 feet to a yard.

```
                175 revolutions
                  8 pitch of wheel
               ----
               1400
                  6 minutes
               ----
    one yard 3)8400 feet in 6 minutes(2800
               6
               --            1760)2800.00(1.59
               24                 1760
               24                 ----
               --                 10400
                                   8800
                                  -----
                                   16000
                                   15840
                                   -----
```

This boat will run one mile and little over one-half mile in 6 minutes.

Rule to find the pitch of a wheel when you know your ship is making 12 knots per hour; to get the pitch of the wheel without taking the ship out of the water, allowing 60 minutes one hour, 15 per cent. off for slip, 120 revolutions, allowing 6080 feet in a mile.

```
one hour 60)6080.0(101.3
            60                    101.3
            ——                       12 knots
              80                  ————
              60                  2026
              ——                  1013
              200                ————
              180   15 off for slip 85)1215.60(143.0
              ———                    85
                                    ———
                                    365
                                    340
                                    ———
                                     256
                                     255
                                     ———
                                      10

Revolutions 120)143.00(11.9 pitch of wheel
                120
                ———
                 230
                 120
                 ———
                 1100
                 1080
                 ————
```

Pitch of wheel is 11 feet and little over.

To find how many miles this ship makes without any slip of the wheel allowing 6080 feet in a mile, 8 feet pitch of wheel, 90 revolutions per minute. How many miles will this ship make in five days?

```
          90 revolutions
           8 pitch of wheel
         ---
         720
           60 one hour
        -----
        43200
           24 one day
       ------
       172800
       86400
      -------
      1036800
            5 days
      ---------
6080)5184000.00(852.63 miles ship makes
      48640                in five days
      -----
       32000
       30400
       -----
        16000
        12160
        -----
         38400
         36480
         -----
          19200
          18240
          -----
```

Rule to find the slip of the wheel when you have an engine counter; the pitch of the wheel 20 feet. The register stands before starting 900, at the finish the register stands 14,000. What is the slip of the wheel?

```
                        14,000
                           900
                        ------
                         13100
                            20 pitch of wheel
                        ------
                        262000 number of feet engine makes
                          6080 one knot
                        ------
                        255920 = 100 per cent.
Number of              --------
 feet engine 262000)255920.00(97 per cent. slip
     makes          2358000
                     -------
                     2012000
                     1834000
                     -------
```

Pressure on piston: What would be the pressure per square inch on a piston 18 inches in diameter with 100 pounds of steam?

```
          .7854                     18
            324                     18
          -----                    ---
          31416                    144
         15708                     18
        23562                      ---
        -------                    324 square inches
   area 254.4696
                100 lbs. steam pressure
        ------------
        25446.9600 = pressure on piston
```

Engine Counter

The counter is used on all steam vessels. To find the number of revolutions the engine makes in 10 days, 14 hours, 13 minutes, and 40 seconds. The engine started with 967 revolutions, and after the voyage the register stood 696049. 696049 − 967 = 695082, when the engine stopped. Now then

```
24   hours one day
 10 days
 ---
240
 14 hours
 ---
254
  60 one hour
-----
15240 minutes
   13 minutes
------
```

```
696049 when stopped
   967 when started
------
695082 difference when
           stopped
```

```
10)40 seconds
    --
     4

10)60 seconds
    --
     6
```

```
15253.4)695082.00(45.56 number of revolutions per minute
         610136
         ------
          849460
          762670
          ------
           867900
           762670
           -------
           1052300
            915204
           -------
```

This engine makes 45.56 revolutions per minute.

Safety Valve

To find the weight to be placed on a lever safety valve: Diameter of valve $4\frac{1}{2}$; steam pressure is 100 pounds; fulcrum is 3 inches; length of lever is 30 inches; weight of lever is 25 pounds; weight of valve and stem is 9 pounds.

```
 25 weight of lever                    4.5 diameter
 15 half length                        4.5
----                                  ----
125                                    225
25        9 valve and stem            180
----      3 fulcrum                  ------
375      --                          20.25
 27      27                          .7854
----                                 ------
402                                    8100
                                      10125
                                     16200
                                    14175
                                   ----------
                                   15.904350 area of valve
                                             100 steam
                                   ------------
                                   1590.435000
                                               3 fulcrum
                                   ------------
                                   4771.305000
                                    402
                                   ------------
              Length lever 30)4369.305000(145.64 weight of ball
                                   30
                                   ---
                                   136
                                   120
                                   ---
                                    169
                                    150
                                    ---
                                     193
                                     180
                                     ---
                                      130
                                      120
                                      ---
```

Safety Valve

If a safety valve area is 7 inches, steam pressure is 60 pounds, fulcrum is 3 inches length, lever 24 inches long, weight of valve and stem 6 pounds, weight of lever 9 pounds, what would be the weight of the ball to be placed on the end of the lever?

```
 12 half length of lever            7  area of valve
  9 weight of lever                60 steam pressure
----                              ----
108      6 valve and stem         420
 18      3 fulcrum                  3 fulcrum
----    --                       -----
126     18                       1260
                                  126 subtract
                                 ------
           Length lever 24)1134.00(47.25 weight of ball
                            96
                           ----
                           174
                           168
                           ----
Work the example back-       60
  ward to find the steam     48
  pressure.                  ---
                            120
 7 area      47.25 ball     120
 3 falcrum      24 lever    ---
--           -----
21           18900
             9450
           -------
           1134.00
            126
           -------
        21)1260.00(60 steam pressure
           126
           ---
```

Safety Valve

We want to find what steam pressure it will take to make a safety valve blow off with a direct weight on top of a valve and stem without any lever; valve is 4 inches in diameter; weight of valve and stem is 12 pounds; the ball weighs 100 pounds.

```
ball 100 pounds              .7854
      12 valve and stem         16 square of valve
     ---                     -----
     112 dead weight         47124
                             7854
                           -------
                           12.5664 area of valve

12.5664)112.00000(8.91 or nearly 9 pounds of steam
        1005312
        -------
         1146880
         1130976
         --------
           159040
           125664
           ------
     112 dead weight
       100 steam
     --------
8.91)11200.00(1257.00
     891
     ---         12.5664)1257.0000(100 weight of ball
     2290                125664
     1782                ------
     ----                    3600
      5080
      4455
      ----
       6250
       6237
       ----
```

It takes 8 pounds 91 one-hundredths, nearly 9 pounds to raise the valve. Then work it backward to find weight.

Rule for a Round Tank

If a tank is 6 feet in diameter what will be the height of the tank to hold 2000 gallons, allowing 231 cubic inches to a gallon?

```
   72 diameter of tank in inches
   72
  ----
  144
 504
  ----
 5184
 .7854
 ------
 20736
25920
41472
36288
--------
231)4071.5136(17.6256
    231
    ----
    1761
    1617
    ----
     1445
     1386
     ----
      591
      462
      ----
      1293
      1155
      ----
      1386
      1386
      ----

  17.6256
       12 constant
  -------
   352512
  176256
  -------
 211.5072

211)2000.00 gallons(9.47 height of tank
    1899
    ----
    1010
     844
    ----
     1660
     1477
     ----
```

Height of this tank is 9.47 nearly $9\frac{1}{2}$.

Round Tank

To find how many gallons this tank will hold, allowing 231 cubic inches to a gallon. The tank is 28 inches in diameter and 4 feet high. Always take the tank in inches when you want to get the gallons.

```
                28 diameter
                28
                --
               224
               56
               ---
               784
             .7854
             -----
              3136
             3920
            6272
           5488
           ---------
           615.7536 area of tank
                 48 height of tank
          ----------
           49260288
          24630144
          ----------
231)29556.1728(127.94 number of gallons this tank will
    231                 hold
    ---
     645
     462
     ---
     1836
     1617
     ----
      2191
      2079
      ----
       1127
        924
       ----
```

Square Tank

To find the number of gallons this square tank will hold, allowing 231 cubic inches to a gallon. Tank is 5 feet 3 inches long, 3 feet 4 inches wide, and 4 feet deep.

```
              63  length of tank
              40  width of tank
            ----
            2520
              48  deep
            ----
           20160
          10080
          -------
    231)120960.00(523.63 number of gallons this tank
        1155                       will hold
        ----
          546
          462
          ---
           840
           693
           ---
           1470
           1386
           ----
             840
             693
             ---
```

Round Tank

To find the number of tons of water this tank will hold, half full, allowing 32 cubic feet per ton. Diameter of tank is 16 feet, and it is 18 feet high.

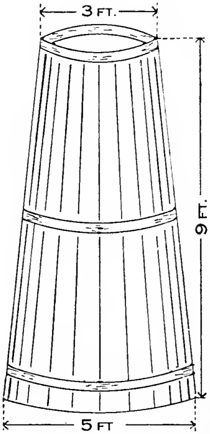
```
diameter 16
of tank  16                  .7854
         --                    256
         96                  -----
        16                   47124
        --                  39270
        256                15708
                           -------
         half tank 2)201.0624(100
                     2
                     --                100
                     01                 18 height of tank
                                       ---
                                       800
                                      100
                                      -----
                      one ton 32)1800.00(56.25 tons
                                 160            of water
                                 ---
                                  200
                                  192
                                  ---
                                   80
                                   64
                                   --
                                   160
                                   160
                                   ---
```

This tank will hold fifty-six tons and a quarter.

Round Tank with Three Dimensions

To find the number of gallons this tank will hold, allowing 7.48 cubic feet to a gallon, the number of gallons in cubic feet. This tank is 3 feet in diameter at the top, 9 feet high, and 5 feet at the bottom.

$$\frac{5^2 + 3^2 + 5 \times 3 = 49 \times .7854 = 38.4846 \times 9}{3}$$ height of tank




```
      .7854
         49
    -------
     70686
    31416
    -------
    38.4846
          9 height
    -------
top 3)346.3614(115.45
      3
      -
      4
      3
      -
      16
      15
      --
       13
       12
       --
        16
        15
        --
```

```
  115.45
    7.48 number of gallons
  ------      in cubic foot
   92360
  46180
 80815
 --------
 863.5660
```

863 gallons in this tank.

Round Tank to Find the Diameter

This tank is 4.02 feet high, containing 400 gallons, allowing 6.25 gallons to a cubic foot.

$$\frac{400 \text{ gallons}}{4.02 \times 6.25} = 15.9 \div .7854 = \sqrt{20.24} = 4.49 \text{ ft. in diameter}$$

```
          4.02 height
          6.25 gallons to cubic foot
          ----
          2010
          804
         2412
        ------    gallons
        25.1250)400.00000(15.900000
                251250
                ------        .7854)15.900000(20.24
                1487500             15708
                1256250             -----
                -------               19200
                 2312500              15708
                 2251250              -----
                 -------

                       20.2400(4.49 square root
                       16
                        --
                     84)424
                        ---
                        336
                        ----
                    889)8800
                        8001
                        ----
```

This tank is 4.49 in diameter nearly $4\frac{1}{2}$ feet.

FLAT BOTTOM BOILER

To find the number of $\frac{7}{8}$-inch stays to put in flat-bottom boiler 18 feet 6 inches long, 12 feet 6 inches wide. The water is 12 feet 10 inches high with 45 pounds of steam, allowing 6000 stress on stay. Constant 2.305 in a column of water 1 foot high and 1 inch in diameter.

```
                                  222   length of boiler (inches)
                                  150  width of boiler
                                 -----
12)10000(8333                    11100
   96                            222
   --                            -----
    40                           33300
    36                             50.5 total pressure
    --                          -------
     40                         166500
     36                        166500
     --                        -------
      40                 3607)1681650.0(466 number of stays
                               14428
                               -----          .875
                                23885         .875 dec. of 7/8
                                21642         ----
                                -----         4375
                                 22430       6125
                                 21642      7000
                                 -----      ------
2.305)12.8333(5.5                           .765625
       11525                                 .7854
       -----                                -------
        13083                               3062500
        11525                              3838125
        -----                             6125000
                                         5359375
             45   steam                 ---------
              5.5 water                .6013318750
             ----                             6000   stress on
             50.5                      ---------------   stay
        Total pressure                 3607.9912500000
```

Flat-bottom boiler, to find steam pressure: Boiler is 14 feet 6 inches long, 10 feet 7 inches wide; 65 stays one inch and a quarter in diameter. The water in boiler 8 feet high, allowing 6000 stress on stay; constant 2.305.

```
                     174 length of boiler
                     127 width of boiler
                    ----
                    1218
                    348
                   174
                   ------
   number  65)22098.0(339.9 square inches held up by one
   stays      195                 stay
              ----
               259
               195
               ----
                648
                585
                ----
                 630            1.25
                 585            1.25 diameter of stay
                 ---            ----
 height of water                 625
2.305)8.0000(3.4                 250
      6915                      125
      -----                    ------
      10850                    1.5625
       9220                     .7854
       ----                    ------
                                62500
   21 steam                     78125
    3.4                       125000
   ---                       109375
   24.4  total pressure     ----------
                             1.22718750
                                   6000 stress on stay
                          --------------
                   339.9)7363.12500000(21 steam pressure
                         6798
                         ----
                          5651
                          3399
                          ----
```

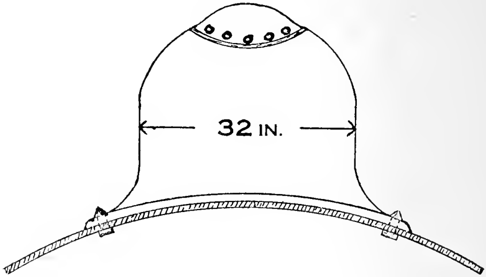
To find the working pressure on a round boiler: Single-riveted boiler, allowing 20 per cent. for double-riveted and holes drilled; diameter of boiler, 5 feet 6 inches; thickness of plate, $\frac{3}{8}$; tensile strength, 60,000; factor of safety, $\frac{1}{6}$.

```
      6)60000(10000              10000
        6                          .375 thickness
        —                        ------
                                 50000
diameter of boiler              70000
      2)66(33 inches           30000
        6                      -------
        —                   33)3750.000(113.63
         6                     33
         6                     ——                113.63
         –                      45                22.72
                                33               -------
                                ——               136.35
                                120
                                 99
   113.63                       ——                steam
      .20                        210             pressure
   -------                       198            136  pounds
   2272.60                       ——
                                 120
                                  99
                                  ——
```

Calculate the safe-working pressure on a corrugated furnace, allowing 14,000 as a constant; thickness of furnace, $\frac{1}{2}$; diameter of furnace, 40 inches.

```
40)14000(350
    120
    ——           350
     200           .5 thickness
     200         -----
     ——          175.0
                 steam pressure
```

To find the number of $\frac{3}{4}$-inch rivets to hold down a steam dome, single-riveted, with 120 pounds of steam; diameter of the dome, 32 inches; $\frac{3}{4}$ rivet, $\frac{13}{16}$ hole; allow 6000 stress on rivet.



.5184 area of $\frac{13}{16}$ hole
6000
———
3110.4000

32 diameter
32 "
—
64
96
———
1024
.7854
———
4096
5120
8192
7168
———
804.2496
120 steam
———
160849920
8042496
———
96509.9520

3110)96509.9520(31
9330
———
3209
3110
———

It will take 31 rivets, nearly 32

To find the diameter of a safety valve to place on a boiler with 75 square feet of grate surface, allowing 3 square feet of grate surface to one inch of area of valve:

```
.7854)25.000000(31.83 square root      Square feet 3)75(25
      23562                                           6
      -----                                           --
       14380                                          15
        7854                                          15
       -----                                          --
        65260
        62832              31.8300(5.64 diameter of valve
        -----              25
         24280             ---
         23562          106)683
         -----              636
                            ---
                       1124)4700
                            4496
                            ----

        Diameter of valve  5.64
             "         "   5.64
                           ----
                           2256
                          3384
                         2820
                         -------
                         31.8096
                           .7854
                         -------
                         1272384
                        1590480
                       2544768
                      2226672
                      -----------
                      24.98325984
                                3 square feet of grate
                      -----------
                      74.94977952
```

74.94 square feet of grate surface nearly 75 feet.

What would be the pitch of a stay bolt if the plate was $\frac{1}{2}$ inch thick, the steam pressure 40 pounds, and thickness of the plate under $\frac{7}{16}$ use constant 112, any thickness of plate over $\frac{7}{16}$ up to $\frac{3}{4}$, use constant 120 squared in 16 of inches?

```
                           120 constant
                            64 in 16 squared
                           ---
                           480
                          720
                          ----
steam pressure 40)7680(192
                  40                square root of 192
                  --               1|92(14 pitch of stay
                  368              1      nearly 14 inches
                  360              -
                  ---            24)92
                    80              96
                    80              --
                    --
```

Rule to find the thickness of plate in a boiler when you have TS and steam pressure and diameter: Diameter of boiler 36 inches, steam pressure is 104 pounds, TS 45,000, factor of safety $\frac{1}{6}$.

```
                              104 steam
                               18 half diameter boiler
6)45000(7500                  ---
  42                          832
  --                         104
   30                        ----
   30                   7500)1872.0(.25 thickness of the
   --                                    boiler
```

The stays of a boiler are $1\frac{1}{2}$ diameter; the steam pressure is 39.27 pounds per square inch; allowing 5000 stress on stay; find the pitch of the stay.

1.5 diameter of stay
1.5 diameter of stay

75
15

2.25 square of stay

.7854
2.25

39270
15708
15708

1.767150
5000 stress on stay

steam 3927)8835.750000(2.25 square root
7854

9817
7854

19635
19635

2.25(1.5 inches pitch of stay
1

25)125
125

Take the same example as above: If the pitch of stay is 1.5 inches, the steam pressure is 39.27 pounds per square inch. Allowing 5000 stress on stay, what would be the diameter of the stay?

39.27 pounds pressure
2.25 square of stay

19635
7854
7854

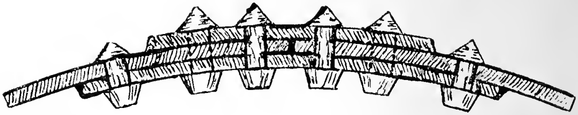
steam 39.27)88.3575(2.25
7854

9817
7854

19635
19635

2.25(1.5 diameter stay
1

25)125
125



A triple-riveted Scotch boiler, 4 rows of rivets in one shear; $\frac{15}{16}$ hole; pitch of double rows of rivets $3\frac{5}{8}$; single pitch $7\frac{1}{4}$; the diameter of the boiler is 72 inches; thickness of plate, $\frac{1}{2}$; tensile strength 55,000, allowing 40,000 for iron rivet; factor of safety $\frac{1}{5}$; but straps the same thickness as the shell of boiler.

.6903 area of $\frac{15}{16}$ hole
40000 iron rivet
27612.0000
This is what the rivet will stand
40000 shearing of the rivet
.85 per cent.
200000
320000
34000.00
40000 shearing of the rivet
74000.00 shearing of all rivets

Shearing of all of the rivets by taking 85 per cent. of the single rivet and adding the single to it gives the shearing of all rivets 74,000.

Triple-Riveted

7.25 long pitch
.5 thickness

3625
55000 TS

18125000
18125

199.375000
constant

7.250 long pitch
.9375 decimal of $\frac{15}{16}$ hole.

6.3125
.5 thickness

315625
55000 TS

1578125000
1578125

199)1735.9375000(87 per cent. *plate section*

2)72(36

36
5

180

.87 per cent.
.5

.435
55000 TS

2175000
2175

180)23925.000(132.8
180

592
540

525
360

1650
1440

constant

.6903 area $\frac{15}{16}$ hole
.4 rows of rivets

.27612
74000 shearing of all rivets

110448000
193284

20432.88000
2761.20000 single rivet added

constant 199)23194.08000(116 rivet shearing
199

329
199

1304
1194

132.8 pounds of steam on this boiler.

To find the diameter of any stay with any given pressure: We will take 7500 pounds pressure per square inch. Allowing 6000 stress on stay, find diameter. Always use .7854 × 6000, gives what a one inch stay will hold, and divide that into the pressure and extract the square root of the answer = diameter of stay.

```
                        pressure
 .7854             4712)7500.00(1.59
     6000               4712
 ---------              -----
 4712.4000              27880            1.5900(1.26
                        23560            1
                        ------           --    diameter stay
                         43200         22)59        1¼
                         42408            44
                         ------           ----
                                     246)1500
                                         1476
                                         ----
```

If the stay in a boiler is pitched 6 × 6 from centre to centre with 120 pounds pressure per square inch, what pressure is on the stay or what pressure is the stay holding up?

```
  6 pitch
  6
 --
 36
 120 steam
 ---
 720
36
----
```

This stay is holding 43.20 pounds

To find the working pressure of steam you would allow on a $1\frac{1}{2}$ round stay, allowing 6000 stress on stay; pitch of stay 6×6 from centre to centre.

1.5 diameter stay
1.5
———
75
15
———
2.25

.7854
2.25 square of stay
———
39270
15708
15708
———
1.767150
6000 stress on stay
———

6
6
—
36

36)10602.900000(294 *steam pressure* on stay
72
——
340
324
——
162
144
——

To find the working pressure per square inch you would allow $1\frac{1}{2}$ square stay, allowing 6000 stress on stay; pitch of stay 6×6 from centre to centre.

1.5
1.5
——
75
15
——
2.25
6000
——

square of pitch 36)13500.00(375 pounds *steam pressure.*

To find the diameter of any stay to hold up any pressure when you have the steam pressure and the pitch of the stay. Now we will take, for example: The pitch of stay is 8 × 8 inches pitch from centre to centre and steam pressure per square is 160 pounds. What is the diameter of the stay? Always use .7854 × 6000 stress on stay.

```
 .7854                 8 pitch
     6000              8
 ---------             --
 4712.4000             64   square of the pitch
                       160 steam pressure
                      ----
                      3840
                      64
                     -----
             4712)10240(2.17 pressure per square inch


              square root
                 2.17(1.47 diameter of stay
                 1
                ---
              24)117
                  96
                ----
             287)2100
                 1909
                 ----
```

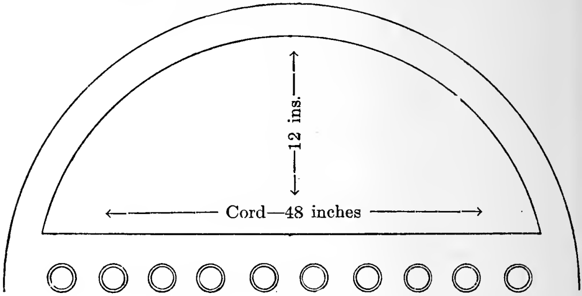
It will take $1\frac{1}{2}$ stay to hold this pressure.

Rule to find: If there were a number of stays in a flat surface, and if one was to give way, what extra pressure would it throw on the other stays in the boiler? The stays are 12 × 12 centre to centre; the stay is $1\frac{5}{8}$ inches in diameter; steam pressure is 70 pounds. What extra strain will be put on the other stays, allowing $\frac{1}{3}$ the pressure after the stay gave away?

```
 12                                    1.625
 12 pitch                              1.625 diameter of stay
 --                                    -----
 24                                     8125
12                                     3250
---                                   9750
144                                  1625
 70 steam                            --------
-----                                2.640625
10080 strain before broke             .7854
                                     --------
                                     10562600
                                    13203125
                                   21125000
                                  18484375
                                 ----------
                   area of stay 2.0739468850

                   2.073)10080.0000(4862.4 after stay broke
3)4862.4(1620.8          8292
 3                       -----
 --                      17880
 18                      16584
 18                      -----                   1620.8
 --                       12960      after broke 4862.4
  6                       12438                  ------
  6                       -----                  6483.2
 --                        5220              strain thrown
   24                      4146                 on stays
   24                      -----
   --                      10740
                            8292
                           -----
```

To find the number of square inches over the top of the tubes in the boiler: height, 12 inches; cord, 48 inches; take $\frac{2}{3}$ cord.



48
2 the cord
——
3)96(32
9
——
6

32
12 height
——
64
32
——
$\frac{2}{3}$ of cord 384
18 one-third cord
——
402 square inches in this space over tubes 402

12 height
12
——
24
12
——
144
12 height
——
288
144
——
twice the cord 96)1728(18 one third of cord
96
——
768
768
——

402 square inches in this space over the tubes.

To find the working pressure of a straight furnace 44 inches in diameter, 48 inches long, thickness of plate ½ inch, using a constant 51.5—10.3—18.75

constant
diameter 44)51.50(1.17
44
——
75
44
——
310
308
——

1.03 constant
48
——
824
412
——
49.44

$\frac{8}{10}$ times the pressure on convexed heads is pressure on concaved head

18.75 constant
.8 = $\frac{8}{10}$
——
150.00
49.44
——
100.56
1.17
——
70392
10056
10056
——
steam pressure 117.6552

Required the working pressure on convex heads, concave heads, radius 52 inches, TS 60,000, thickness of plate ½, factor of safety $\frac{1}{5}$.

5)60,000(12,000
5
—
10
10

12,000
.5 thickness
——
half radius 26)6000.0(230
52
——
80
78
——
20

230
.8
——
184.0

230 pounds on convexed head.
184 pounds on concave head.

The correct rule to find the working pressure on any boiler and percentage of the plate compared to the solid part of the boiler and the rivet shear:

Pitch of rivet $2\frac{3}{4}$, hole or rivet $\frac{13}{16}$, thickness of plate $\frac{3}{8}$, two rows of rivets, TS 50,000, diameter of boiler 60 inches, factor of safety $\frac{1}{6}$, allowing 45,000 for steel rivet.

2.75 pitch of rivet
.375 thickness of plate
———
1375
1925
825
———
103.125
constant

2.7500 pitch
.8125 decimal $\frac{13}{16}$
———
2.75)1.9375(70 percentage of plate
1925
———
125

area of $\frac{13}{16}$ hole .51849
.2 rows of rivets
———
constant 103)10369.8(100

30
6
——
180

.70 per cent.
.375
———
350
490
210
———
.26250
50000 TS
———
180)13125.00000(72 *steam pressure*
1260
———
525
360
———

100
45000 steel rivet
———
500000
400
———
TS 50000)4500.000(90 *rivet shear*)
450
——

To find the tensile strength of a boiler, single-riveted, with holes drilled; steam pressure 125 pounds, diameter of boiler 40 inches, thickness of plate $\frac{1}{4}$ inch, factor of safety $\frac{1}{6}$.

```
                        125 steam
                          6 factor safety
                        ---
                        750
                          20 half diameter boiler
                       ------
thickness .25)15000.00(60000 TS of plate
              150
              ---
```

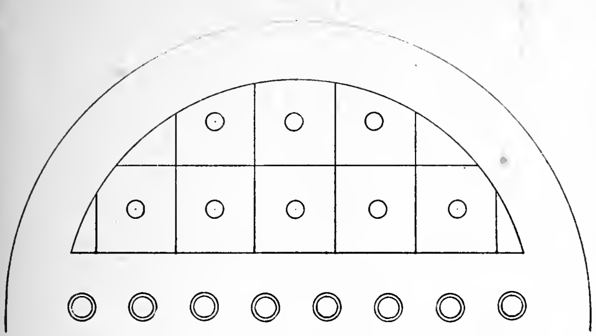
To find the diameter of the same boiler as above: TS 60.000, thickness of plate $\frac{1}{4}$, steam pressure 125 pounds, factor of safety $\frac{1}{6}$.

```
steam 125                60000 TS
        6 safety           .25 thickness
      ---               ------
      750               300000
                       120000
                      -------
                  750)15000.00(20
                      1500
                      ----
                                       20
                                        2 always twice
                                       --
                                       40 diameter of boiler
```

Diameter of boiler is 40 inches.

The rule for bracing the head of a boiler above the tubes:

For example, will say that we have to brace in this boiler 353.77 square inches, the load to be carried by the braces will be equal to the area multiplied by the working pressure, which is 130 pounds per square inch: total load, $353.77 \times 130 = 45{,}990$ pounds. No boiler brace should be allowed greater stress than 6000 pounds per square inch. The number of braces required may be found by dividing the total load by what one brace will stand, which in this case is $45{,}990 \div 6000 = 7.66$, say 8 braces having an area of one inch square, which corresponds to about $1\frac{1}{8}$ inches in diameter. The surface or area supported by each brace is found by dividing the area to be supported by the number of braces, which gives $353.77 \div 8 = 44.22$ square inches; the square root of this number will give the distance between the braces or the pitch which is 6.64 inches or $6\frac{10}{16}$.



Example for bracing the head of the boiler:

353.77 square inches
130 steam

1061310
35377

one brace 6,000)45990.10(7.66 number of stays—will say 8
42000

39901 stays 8)353.77(44.22
36000 32 inches held up by one stay

39010 33
36000 32

square root 44.2200(6.64 17
36 inches held up by one stay 16

126)822 17
756 16

1324)6600
5296

6.64 square inches held up by one stay. In other words, 6.64 is pitch of stay.

The quickest way to get the horse-power of a boiler is to get the number of square feet of the grate surface. We will say that we have got 50 square inches of grate surface, multiplied by 50, multiplied by constant of 45, allowing 14 square feet to a horse-power. Example:

```
                          50
                           50
                         ----
                         2500
                           45 constant
                        -----
                        12500
                       10000
                      -------
one square ft. 144)112500.0(781.2
                      1008                  14)781.2(55.8 horse
                      ----                      70          power of
                       1170                     --           boiler
                       1152                     81
                       ----                     70
                         180                    --
                         144                   112
                         ---                   112
                          360                  ---
                          288
                          ---
```

This boiler has 55.8 horse-power.

Rule to find the correct pitch of rivets in a single-riveted seam of a boiler: If the thickness of the plate is $\frac{3}{8}$, and the tensile strength is 60,000, the rivet $\frac{7}{8}$, the hole is $\frac{15}{16}$, the shearing strength of the rivet is 40,000, then proceed. The area of $\frac{15}{16}$ hole is $.6903 \times 40{,}000$, gives you the strength of the rivet, which is $27612.0000 \div$ by $\frac{3}{8} \times 60{,}000 = 22500$ and $27612.0000 \div 22500 = 1.2272$; nearly $1\frac{1}{4}$ add the diameter of the hole: $1\frac{1}{4} + \frac{15}{16} = 2\frac{3}{16}$ pitch.

.6903 area of $\frac{15}{16}$ hole
40000 rivet
—————
27612.0000 strength of rivet

22500)27612.0000(1.2272 nearly $1\frac{1}{4}$ pitch
22500
—————
51120
45000
—————
61200
45000
—————
162000
157500
—————
45000
45000
—————

1.25
dec. of $\frac{15}{16}$ .9375
—————
$2.1875 = 2\frac{3}{16}$ pitch

Rule to find the correct pitch of double-staggered riveted lap-joint where the plates are made of steel $\frac{3}{8}$ of an inch thick; tensile strength of the plate is 55,000, the diameter of rivet is $\frac{7}{8}$, the diameter of hole is $\frac{15}{16}$, allowing 40,000 pounds shearing strength for rivet; two rows of rivets.

.375 thickness $\frac{3}{8}$
55,000 TS
―――――
1875000
1875
―――――
20625.000

.6903 = area of $\frac{15}{16}$ hole
2 rows of rivets
―――――
13806
40,000 shearing of rivet
―――――

20625.000)55224.0000(2.6775
41250
―――――
139740
123750
―――――
159900
144375
―――――
155250
144375
―――――
108750
103125
―――――

2.6775
.9375 dec. of $\frac{15}{16}$
―――――
3.6150 = $3\frac{9}{16}$
pitch of rivet

Pitch of this rivet is $3\frac{9}{16}$.

Rule to find the coal burned per hour by indicated horse-power: Diameter of cylinder 42 inches, 48-inch stroke, 65 revolutions per minute, the diagram showing 55.6 pounds mean effective pressure on piston, consuming 30 tons of coal per day. Calculate the indicated horse-power developed and the consumption of coal per hour indicated horse-power.

```
stroke 48                            .7854
        2 twice                      1764 cylinder squared
       ——                            ————
       96                           31416
       65 revolutions              47124
      ———                         54978
     480                          7854
    576                         ——————————
    ————                        1385.4456
  12)6240(520                        55.6 mean effective pressure
    60                            ——————————
    ———                           83126736
     24                          69272280
     24                         69272280
     ——                        ————————————
                              77030.77536
                                        520 feet per minute
                              ——————————————
                              154061550720
                             38515387680
                             ———————————————
                        33)40056.00318720(1213.8 horse-power
                             33
                             ——
                             70     1213.8)2800.000(2.31 pounds
         2240                66              24276     per hour
            30               ——              —————     per horse-
one      —————               45               37240    power
day  24)67200(2800           33               36404
         48                  ——               —————
         ——                  126               18460
         192                  99               12138
         192                  ——               —————
         ———                  270
                              264
                              ———
```

Rule to find the working pressure of steam you would allow on a straight furnace per square inch: diameter 44 inches, length 48 inches, thickness of furnace $\frac{1}{2}$, using three constants.

Constants:
51.5
18.75
1.03

diameter 44)51.5(1.17
44
75
44
310
308

1.03
48 length
824
412
49.44

18.75
.8 = $\frac{1}{2}$
150.00
49.44
100.56
1.17
70392
10056
10056
117.6552

Steam pressure is 117 pounds.

The correct way to find the lift of a valve. We will take a three-inch valve:

```
3 in. valve                      .7854
3 in. valve                          9 square of valve
-                                -------
9                      9.4248)7.068600(.75 = 3/4 lift of valve
                                659736
                                ------
                                 471240
constant 3.1416                  471240
              3 diameter         ------
         -------
         9.4248 of valve
```

There is another way to get the lift of the valve by dividing by $\frac{1}{4}$ the diameter of the valve. Take the same valve as above, 3 inches in diameter:

```
4)3.00(.75 = 3/4
  28
  --
   20
   20
   --
```

If you had one ton of coal and 300 pounds of ashes, what percentage of ashes would you have? Example:

```
                300 ashes
                  100 per cent.
                -------
one ton 2240)30000.00(13.39 percentage of ashes
             2240
             ----
              7600
              6720
              ----
               8800
               6622
               ----
               21800
               20160
               -----
```

Coal Bunker

To find how many tons of coal this bunker will hold, allowing 40 cubic feet per ton. We will take this bunker in inches when you cannot get it in feet. Where you have three dimensions in feet, multiply the three dimensions in feet and you have cubic feet; where you cannot get it in feet, take it in inches and proceed this way:

```
Length 18 ft 6 in.                      222 length in inches
Depth 10 ft. 4 in.                      124 depth in inches
Width 6 ft. 3 in.                       ---
                                        888
                                       444
                                      222
                                      -----
                                      27528
                                         75 width in inches
                                     ------
                                     137640
                                    192696
                                    -------
           one cubic foot 1728)2064600(1194.00
                                   1728
                                   ----   40)1194.00(29.85
                                    3366      80          tons
                                    1728      ---
                                    ----      394
                                    16380     360
                                    15552     ---
                                    -----      340
                                      8280     320
                                      6912     ---
                                      ----      200
                                                200
                                                ---
```

This bunker will hold 29.85 tons.

Coal Bunker

To find the third dimension of a coal bunker to hold 40 tons of coal, allowing 42 cubic feet per ton. depth of bunker is 15 feet 6 inches, width of bunker is 12 feet 6 inches:

```
                         186  depth
                          150 width
                         ----
                         9300
                        186
                        -------
one square foot 144)27900.00(193.75
                    144
                    ----
                    1350
                    1296
                    ----
                      540
                      432
                     ----
                     1080                 42 cubic feet
                     1008                  40 tons
                     ----                --------
                       720      193.75)1680.0000(8.67
                       720             155000   length
                       ---             -------    of
                                        130000  bunker
                                        116250
                                        -------
                                         137500
                                         135625
                                         -------
```

Length of this bunker is 8.67.

Take page 96; you will find the bunker is figured in feet instead of inches.

Coal Bunker

Take the same bunker as page 95. This bunker is done in feet to show you how to figure it in inches when you cannot get it in feet: Depth of bunker 15 feet 6 inches, width 12 feet 6 inches, to hold 40 tons of coal, allowing 42 cubic feet per ton:

```
   15.5 depth
   12.5 width
   ----
    775
   310
  155
  -----
 193.75                   42 cubic feet
                           40 tons
                         --------
               193.75)1680.0000(8.67 length
                      155000
                      ------
                       130000
                       116250
                       ------
                        137500
                        135625
                        ------
```

Length of this bunker is 8.67.

Coal Bunker

To find the average width of a coal bunker: Length of bunker, 45 feet; depth of bunker, 16 feet; top of bunker, 25 feet; middle of bunker, 18 feet; bottom of bunker, 10 feet. Always divide by 6.

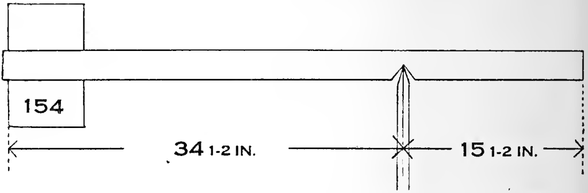
```
   25 top of bunker
   72 four times middle
   10 bottom
  ------
6)107.00(17.83 average width nearly 18 feet
   6
  --
   47
   42
   --
     50
     48
     --
      20
      18
      --
```

Coal Bunker

To find the average width: Top 10 feet, bottom 5 feet. Always divide by 2 to get average width.

```
                       10 top
                        5 bottom
                       ---
Average width 7½     2)15.0(7.5
                       14
                       --
                        10
```

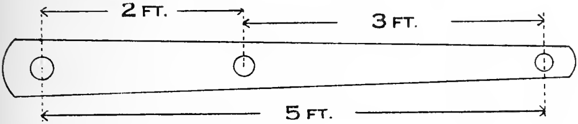
Rule to balance weight on end of a lever; this lever has a weight of 154 pounds on the long end; the long arm is $34\frac{1}{2}$ inches; the short arm is $15\frac{1}{2}$ inches; what weight will it take on the short arm to balance the weight (154 pounds) on the long arm?



154 weight on long arm
34.5 length of long arm
———
770
616
462
———
short arm 15.5)5313.0(342 weight of ball on *short arm*
465
———
663
620
———
430
310
———

It will take a weight 342 pounds to balance the lever.

To find the stroke of an air pump when you have the dimensions of the air pump beam and the stroke of the engine. We will say the stroke of the engine is 3 feet, the length of the air pump beam is 5 feet over all, the long arm is 3 feet, and the short arm is 2 feet.

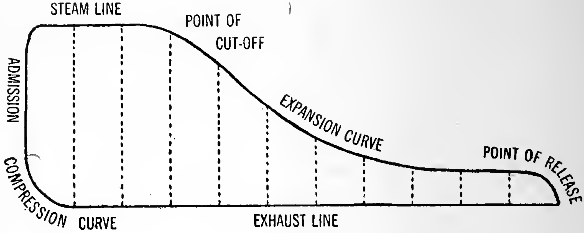


This example is done in two ways; one way in feet and the other in inches.

3 stroke of engine
2 short arm
—
Long arm 3)6(2 stroke of air pump 2 feet
6
—

36 stroke of engine
24 short arm
—
144
72
—
Long arm 36)864(24 stroke of air pump 24 inches
72
—
144
144
—

To Point Off an Indicator Card



The correct way to get the mean effective pressure on the piston is to lay your card out in 10 equal parts; each one of the lines denotes pounds of steam; take your scale, measure the length of each line, put it down on paper, then count it up; then multiply by the spring you use and divide by the 10 spaces on your card; that will give you the mean effective pressure.

Rule to Find the Pressure on a Piston.

If the pressure of steam on the piston is 70 pounds when the engine is working full speed at 62 revolutions, and the speed becomes reduced to 50 revolutions, what would the steam pressure be?

revolutions 62
62
124
372
3844

70 steam pressure
50 revolutions reduced
3500
50 reduced revolutions
3844)175000.00(45.52 reduced steam pressure
15376
21240
19220
20200
19220
9800
7688

To find the total pressure on a shaft either in pounds or tons: Mean effective pressure is 100 pounds, the area of the piston is 350, stroke of the engine 24 inches, pitch of wheel 8 feet, revolutions of engine are 90 per minute.

90 revolutions
4 stroke
360 feet per minute

90 revolutions
8 pitch of wheel
720

.350 area of piston
100 mean effective pressure
35000
360 feet per minute
2100000
105000
720)12600.000(17500 pounds
720
5400
5040
3600
3600

2240)17500.00(7.81 tons
15680
18200
17920
2800
2240

To find the thickness of a corrugated furnace, and find the diameter of the furnace: Steam pressure is 175, diameter of furnace 40 inches, thickness of the furnace is $\frac{1}{2}$, constant 14,000.

```
      175 steam
       40 diameter
     ------
14000)7000.0).5 thickness
      70000
      -----
```

```
                   14000 constant
                      .5 thickness
                   ------
steam 175)7000.0(40 diameter.
           700
           ---
```

To find the weight of a safety-valve weight that is round: Get the diameter of the ball, then square it, then cube it, multiply it by a constant of 9, then divide it by a constant 64.

```
               7 diameter ball
               7 diameter ball
              --
              49
               7 cube it
              --
             343
               9 constant
           -----
constant 64)3087.0(48.2 weight of ball
            256
            ---
             527
             512
             ---
              150
              128
              ---
```

To find the area of any diameter without using .7854. We will take 5 inches in diameter; first square it, then multiply it by .77, then multiply your answer by 2 twice; keep one figure to the right twice.

```
       .7854                          5 diameter
         .25                          5 diameter
      ------                          -
      39270                          25
     15708                          .77
     -------                        ---
    19.6350 area                    175
                                   175
                                     350
                                       350
                                   -------
                                   19.6350 area
```

Example: To find the diameter of a shaft and to find the diameter of the steam pipe of a compound engine: High-pressure cylinder is 13 inches in diameter, low pressure cylinder is 27 inches in diameter, one-fifth of the low pressure cylinder is the diameter of the shaft; and one-quarter the diameter of the shaft subtracted from the diameter of the shaft is the diameter of the steam pipe.

```
  l. p. c.
5)27.0(5.40 diameter of shaft
  25
  —            4)5.40(13.5 one-quarter of shaft
   20            4
   20            —
   —             14
                 12
                 ——
                  20        5.40 diameter of shaft
                  20        1.35 one-quarter of shaft
                  —         ————
                            4.05 diameter of steam pipe
```

The diameter of the steam pipe is 4.05, and the diameter of the shaft is 5.4.

Example: To find the diameter of a steam pipe when you have the horse-power of the engine, using a constant of 6; we will say the horse-power is 150.

```
6)150(25
  12
  ——      25(5 diameter of steam pipe 5 inches
   30     25
   30     —
   —
```

Example: To find how many times the steam expands in compound engine and triple-expansion engine: Steam pressure 69 pounds, atmospheric pressure 15 pounds, 12 pounds pressure on the low-pressure cylinder.

```
                      69 steam pressure
                      15 atmospheric pressure
                      —
pressure on low 12)84(7 steam expands 7 times
                      84
                      —
```

Example: A blow-off cock on the bottom is 14 feet below the sea level and 9 feet below the water level in the boiler. What pressure per square inch would be required to blow the water out of the boiler?

$$\frac{14-9}{2.305}$$

```
           14
            9
           --
  2.305)5.00000(2.16
          4.610
          -----
           3900
           2305         2 pounds—nearly 3 pounds.
           ----
          15950
          13830
          -----
```

Example: To find the number of gallons of oil a barrel will hold, allowing 231 cubic inches in United States gallon: Take the largest part of the middle of the barrel and get the area of it, then multiply by the length in inches, then divide by 231 = number of gallons; diameter of barrel 18 inches, length 36 inches.

$$\frac{18 \times 18 \times .7854 \times 36}{231} = \text{gallons}$$

The Question is Sometimes Asked: What is Steel?

Steel is iron with a mixture of carbon or an alloy of iron, the alloy being principally carbon steel. Steel can be melted like cast iron and welded like wrought iron. There are hard and soft steels, according to the process of production and proportion of alloy.

The Question is Sometimes Asked: What is Alloy?

Alloy is a mixture or compound of two or more metals. Two parts of tin and six parts of lead is an alloy suitable for fusible plugs, and which melts at 380° Fahrenheit. An alloy is used to reduce the quality of one of the parts.

Rule to Find Size of a Cylinder

Rule to find the size that a cylinder should be in diameter: In the example we have $15\frac{1}{4}$ tons on piston and 64 pounds of steam on piston; then multiply $15\frac{1}{4}$ by 2240 pounds in one ton, then divide by the steam pressure, then divide by .7854, then get the square root of the answer, and that will give you the diameter of cylinder.

```
                         15.25  tons on piston
                          2240  one ton
                        ------
                         61000
                        3050
                       3050
                      --------
Steam pressure 64)34160.00(533.75
                  320
                  ---         Constant .7854)533.7500(679
                   216                        47124
                   192                        -----
                   ---                         62510
                   240                         54978
                   192                         -----
                   ---                          75320
                    480                         70686
                    448                         -----
                    ---
                     320
                     320
                     ---

                          6|79(26 diameter of cylinder
                          4
                          --
                       46)279
                          276
                          ---
```

Diameter of cylinder is 26 inches.

Rule to get the area of any diameter: First square the diameter, then multiply by .7854 = the area. Now to find the diameter: Divide the area by .7854, then get the square root of the answer = diameter. We will take a 10-inch valve.

```
        10 diameter
         10              .7854
        ----               100
        100            --------
                       78.5400 area of 10
.7854)78.5400(100
        7854
        ----
                               1|00(10  diameter of
                               1          valve
                              ---
                             2)000
```

Rule to find the horse-power of your dynamo: Multiply your volt meter by your amperes, and divide by 746 watts, will give you the horse-power of your dynamo; 746 watts equal one horse-power.

Rule to Find the Speed of a Wheel.

Rule to find the speed which a wheel on a stationary engine has to make to comply with the law; the limit speed is 6000 revolutions in feet per minute. We will take a wheel 10 feet in diameter; revolutions per minute are 125.

3.1416
10 diameter of wheel

31.4160
125 revolutions

1570800
628320
314160

feet per minute 3927.0000 this will make 3927 feet per minute.

Rule to get the area of any stay under one inch: We will take $\frac{7}{8}$ stay; we will get the area the quickest way.

	.7854		
8	49	square the seven	7
8			7
64	70686		49
	31416		

64)38.4846(.6013 area of $\frac{7}{8}$ stay
384

84
64

206
192

Rule to find the inside diameter of a cylinder with 22 bolts in cylinder head six and a half inches apart, allowing $2\frac{1}{2}$ inches on each side of cylinder head to be taken off; constant 3.1416.

```
      22 number of both
     6.5 apart
    ----
    110
   132
   ------
3.1416)143.00000(45.5
   125664
   ------
    173460
    151780
    ------
     162800
     157080
     ------
```

```
45.5
 5.   off of each side
----
40.5
diameter of cylinder 40.5
```

Rule to find how many pounds of coal and how many tons of coal a boiler will burn in 24 hours, allowing 2000 pounds to a ton, with 75 square feet of grate surface, 15 pounds of coal to square foot of grate.

```
         75 grate
         15 pounds square foot
        ---
        375
        75
       ----
       1125
         24 one day
       ----
       4500
      2250
      -----
2000)27000.0(13.5 tons in 24 hours
      2000
      ----
       7000
       6000
       ----
       10000
       10000
       -----
```

Rule to find how many bolts, $1\frac{1}{2}$ inches in diameter, are required for a cylinder cover 56 inches in diameter, the steam pressure being 90 pounds per square inch, the working strain on the bolts not to exceed 2000 pounds per square inch.

$$\frac{56 \times 56 \times .7854 \times 90}{1.5 \times 1.5 \times .7854 \times 2000} = 62 \text{ bolts, say 63 bolts}$$

```
        56 diameter of cylinder
        56     "           "
       ----
       336          1.5 diameter of bolt
      280           1.5
      ----          ---
      3136           75
     .7854          15
     -----          ---
     12544          225
    15680
   25088
  21952
 ---------
 2463.0144
        90 steam
-----------
221671.2960

3534)221671.0(62.7 nearly 63
     21204         bolts
     -----
      9631
      7068
      -----
      25630
      24738
      -----
```

```
    .7854
    2.25  square feet
   ------
   39270
  15708
 15708
 --------
 1.767150
     2000
 -----------
 3534.300000
```

Rule to find the number of bolts, when the diameter of the bolt and the pitch are given; may be found by the following rule: The diameter of the cylinder cover is 33 inches, the centre of the bolts from edge of cylinder is $1\frac{1}{2}$ inches from edge, the pitch of the bolts is $3\frac{1}{4}$ inches. How many bolts will be required in cylinder cover?

$$33 - (1\tfrac{1}{2} \times 2) = 30 \text{ diameter of cover.}$$

$$\frac{30 \times 3.1416}{3.25} \text{ pitch of bolt}$$

```
1.5        33
  2         3.0
---        ---
3.0        30.0 diameter of cover

              3.1416
                 30 diameter of cover
             -------
pitch 3.25)94.248.0(28.9 number of bolts, say 29 bolts
             650
             ----
             2924
             2600
             ----
              3248
              2925
              ----
```

It will take 29 bolts in this cylinder cover.

Rule to find the indicated horse-power required to exert a given thrust or power on a thrust block may be found by the following example: What indicated horse-power would be required to exert a force or thrust of 27,500 pounds on a thrust block with a screw propeller of 20 feet pitch, making 60 revolutions per minute, allowing 33,000 one horse-power if the slip be 10 per cent.?

$$\frac{27500 \times 20 \text{ pitch} \times 60 \text{ rev.}}{33{,}000} = 1000 \textit{ horse-power}$$

$\frac{1000 \times 10 \text{ slip}}{100} = 100$ horse-power and the power actually employed will be $1000 - 100 = 900$ horse-power

The horse-power would be 900.

Rule to find the pressure per square inch of steam on a piston by the indicated horse-power of an engine. Indicated horse-power of an engine is 180, the diameter of the cylinder is 17 inches, length of stroke is 2 feet, and the number of revolutions per minute are 80. What is the pressure on the piston per pound per square inch?

180 horse-power
33000
———
540000
540
———
72633)5940000(81.7 pounds
581064
———
129360
72633
———
567270
508431
———

17 diameter of cylinder
17 diameter of cylinder
——
119
17
——
289
.7854
——
1156
1445
2312
2023
———
226.9806
320 stroke in feet
———
45396120
6809418
———
72633.7920

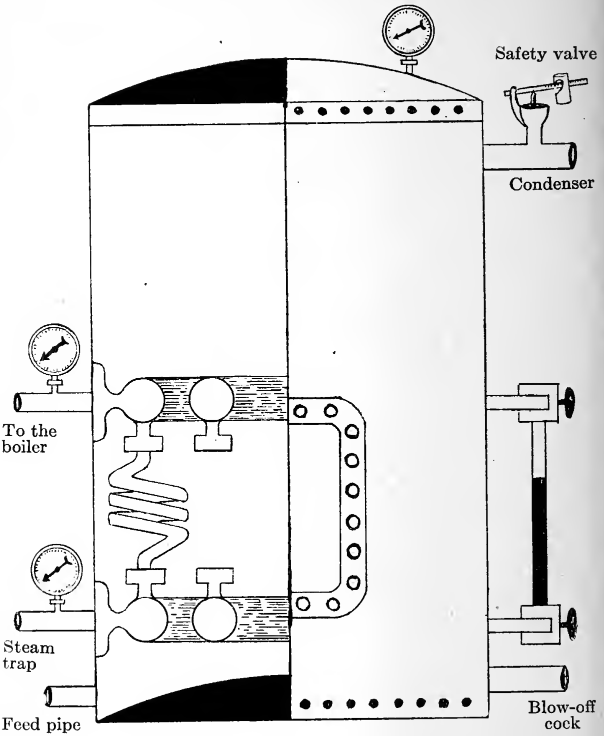
2 stroke
2 stroke
—
4
80 revolutions
——
320

Pressure per square inch on piston is 81.7.

Rule to find the required time to pump a given quantity of water, when two or more pumps of different sizes are employed to empty a tank, may be found by the following example: Divide the product of the time in which each pump will separately empty the tank by the sum of the time required by each pump to separately empty the tank. The water-ballast pump will empty a tank in 3 hours, and the boiler pump will empty it in 10 hours. In what time can the tank be emptied by both pumps working together?

$$\frac{3 \times 10}{3 + 10} = 2 \textit{ hours and } 18 \textit{ minutes.}$$

```
13)30(2 hours and 18 minutes takes to empty
   26       tank
   --
    4
    60 one hour
   ---
13)240(18 minutes
   13
   ---
   110
   104
   ---
```



An evaporator is a vessel in the form of a vertical boiler in which there are two manifolds connected together by a number of copper pipe-coils. The upper manifold is connected to the auxiliary steam line, the bottom manifold is connected to a steam trap and to the condenser, the evaporator is partly filled with water, and live steam is admitted to the upper manifold and passes through the coils and

bottom manifold and into the steam trap; the hot steam in the coils evaporates the surrounding water into steam and is then allowed to pass into the condenser through a pipe connected at the top of the evaporator, and, after being condensed, is used as fresh water, to put in the main boilers.

Rule to Find the Horse-power.

Rule to find the horse-power it will take to run a number of incandescent electric lights 16 candle power, allowing $3\frac{1}{2}$ watts to a candle power, and 1000 watts is equal to $1\frac{1}{3}$ horse-power. We will take 1000 lamps, 16 candle power. What size engine will it take to run 1000 lamps allowing $3\frac{1}{2}$ to candle power? Example:

Add 10 per cent. to the horse-power for friction.

16 candle power lamp
3.5 watts to a candle power
———
80
48
———
56.0 watts to a 16 candle power lamp
1000 lamps 16 candle power each
———

Lamps 1000)56000.0(56 total watts, this is 56 Kilowatt machine
5000
———
6000
6000
———

$1\frac{1}{3}$ horse equal 1000 watts.
———
56
$18\frac{2}{3}$
———
$74\frac{2}{3}$ we would say 75 horse-power

75 horse-power
7 percentage
———
82 horse-power, best to say 90 horse-power

If you had 200 volts and wanted to find what amperage you ought to have, then 56,000 watts $\div 200 = 280$ amperes.

Rule to find the bursting pressure of a boiler, assuming the heads of the boiler are equally as strong as the shell of the boiler: Diameter of the boiler 72 inches, thickness of the plate $1\frac{7}{16}$ = .4375, tensile strength of the plate is 55,000, allowing 70 per cent. strength of the seam.

$$\frac{55{,}000 \times .4375 \times 70}{\text{Radius of boiler}}$$

```
          .4375 thickness
           55000 tensile strength
         ---------
         21875000
        21875
        ----------
       24062.5000
                .70 strength of seam
      -------------
half diameter of boiler 36)16843.750000(467.88 bursting
                           144                  pressure
                           ---
                            244
                            216
                            ---
                             283
                             252
                             ---
                              317
                              288
                              ---
                               295
                               288
                               ---
```

Rule to find the working pressure when you get the bursting pressure of a boiler, assuming the heads of the boiler are equally as strong as the shell of the boiler: Diameter of the boiler 72 inches, thickness of the plate $\frac{7}{16}=.4375$, tensile strength of the plate is 55,000, allowing 70 per cent. strength of the seam, factor safety $\frac{1}{5}$.

$$\frac{55{,}000 \times .4375 \times .70}{36 \times 5}$$

```
                    .4375
                     55000 T. S.
                   ----------
 36 half boiler     21875000
  5 factor safety  21875
 ---               ----------
180                24062.5000
                            .70 strength at seam
                 ------------
             180)16843.750000(93.57 safe working pressure
                 1620
                 ----
                   643
                   540
                   ----
                   1037
                    900
                   ----
                    1375
                    1260
                    ----
```

What is the proper diameter of the feed pipe in inches of an engine whose nominal horse-power is 140, constant multiplier .04, constant to be added 3?

```
                       140
                       .04 constant multiplier
                       ---
                       5.60
                       3    constant to be added
                       ----
take square root  8.60(2.93 diameter of pipe
                       4
                       ---
                    49)460
                       441
                       ---
                   583)1900
                        1749
                        ----
```

What is the proper area of the injection pipe in square inches of an engine whose nominal horse-power is 140, constant multiplier .069, constant to be added 2.81?

```
                 140
                .069 constant multiplier
                ----
                1260
                840
               -----
               9.660
               2.81 constant to be added
               -----
answer 12.470 area of pipe
```

To find the proper diameter of an air pump. Rule: Multiply the diameter of the cylinder in inches by .6. Example: Let 40 inches be diameter of the cylinder then 40 inches × .6 = 24.0; which is the proper diameter of the air pump on this engine.

40 diameter of cylinder
.6
———
24.0 inches diameter of air pump

To find the proper diameter of a crank-pin journal: Multiply the diameter of the cylinder in inches by .142. Example: Diameter of cylinder 40 inches × .142 = 5.680, the proper diameter of crank pin.

.142 constant
40 diameter of cylinder
———
5.680 diameter of crank pin

To find the proper length of crank pin by diameter of the cylinder.

Example: Diameter of cylinder is 40 inches × .16 = 6.40 is length crank pin.

.16
40 diameter of cylinder
———
6.40 length of crank pin in inches

To find the proper diameter of a piston rod by the diameter of the cylinder: Let the diameter of the cylinder be 40 inches ÷ 10 equal diameter of the piston rod.

$$\begin{array}{r|l} 10)40 & (4 \text{ diameter of piston rod} \\ \underline{40} & \end{array}$$

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